ANALYSIS OF SPACECRAFT ON-ORBIT ANOMALIES AND LIFETIMES

PRC R-3579

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER

under

Contract No. NAS 5-27279

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FOREWORD

This report presents the results of a study of spacecraft on-orbit anomalies and lifetimes. The basic source of information is an update of a data bank of on-orbit spacecraft reliability data compiled by Planning Research Corporation (PRC) for the National Aeronautics and Space Administration and the Navy Space Systems Activity in a series of short term contracts starting in 1966. The update covers spacecraft operating since 1977 under the cognizance of the Goddard Space Flight Center and the Jet Propulsion Laboratory. Emphasis in this study is on individual spacecraft and their postlaunch performance degradation over time as a function of component failures and other incidents of anomalous behavior. By contrast, earlier studies in this series concentrated on compiling reliability statistics for hardware elements across spacecraft.

The NASA Technical Monitor for this study was Mr. Edward Shockey of the Goddard Space Flight Center, Code 302. The work was performed during the period June 1982 through January 1983, under NASA Contract NAS 5-27279.

The authors of this report are Charles E. Boomquist and Winifred C. Graham. Other members of the PRC study team were Patricia Alverson and Vera Little. Library assistance was provided by Wendy Christensen and report production support by Brenda Healy.

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ABSTRACT

Analyses of the on-orbit performance of forty-four unmanned NASA spacecraft operating in the past five years (1977-1982) are presented. Included are detailed descriptions and classifications of over 600 anomalies - each anomalous incident represents one reported deviation from expected spacecraft performance. Charts depicting satellite lifetimes and the performance of their major subsystems are included. Engineering analyses to further investigate the kinds and frequencies of various classes of anomalies have been conducted. An improved method for charting spacecraft capabilty as a function of time on orbit is explored.

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I. INTRODUCTION

This study has examined the orbital performance records of forty-four unmanned spacecraft under the cognizance of the Goddard Space Flight Center and the Jet Propulsion Laboratory. Particular attention has been given to each recorded incident of anomalous behavior. These incidents, referred to herein as anomalies, range from momentary "glitches" in otherwise normal spacecraft operation to complete spacecraft failure. The basic data have been collected, reduced, analyzed and reported in formats consistent with those in the existing data bank, developed by Planning Research Corporation (PRC). These earlier data were collected on 350 spacecraft under several discrete contracts awarded to PRC between 1966 and 1979.

A. Study Objectives and Scope

One of NASA's primary concerns is to improve the performance of its spacecraft, both manned and unmanned. For unmanned spacecraft, longevity is a key parameter. Generic approaches to improving longevity are of continuing interest to NASA; the search for such approaches is the motivation for this study. There are two study objectives. The first is to establish a current data base of on-orbit spacecraft anomalies and performance summaries following previous PRC work in this area but extending it somewhat to support the second study objective. The second objective is to develop a method for quantifying spacecraft performance as a function of time on orbit which extends and improves upon an existing methodology, previously developed by PRC and applied to other spacecraft in the data bank.

Augmentation of the data base is limited to spacecraft launched under the auspices of the Goddard Space Flight Center (GSFC) or the Jet Propulsion Laboratory (JPL) and which have been operational since the last general update of the space data bank in 1977-1978.

B. Background

The first 15 references at the end of this report trace the compilation and utilization of the PRC data bank. Reference 1 was the result of an initial study undertaken in 1966 to respond to the need for more accurate and detailed spacecraft reliability data than were available in the mid-sixties. On-orbit data from 225 spacecraft were compiled and analyzed. The resultant report was well received and widely distributed. Subsequently, several specific analyses of these data were conducted and reported on (see References 2-6). Reference 7 was an extensive update of Reference 1; the size of the data base essentially doubled. Reference 9 added still more data resulting from a modest collection effort in 1972. References 8 and 10 through 14 reported on various special-purpose analyses of the data bank. Reference 15 reported on another comprehensive update and consolidation of the data bank conducted in 1978. At the conclusion of that study, the PRC data bank included on-orbit performance data on some 350 different spacecraft. All basic spacecraft data collected from the beginning of these efforts were included in the Reference 15 study report. Reference 16 analyzed and interpreted orbital reliability data for U.S. meteorological satellites in the data bank.

C. Organization of the Report

Section II briefly describes the data base and the updating of it for purposes of this study. It includes a description of collection and reduction procedures and baseline data on all spacecraft included in the update. Section III classifies the anomaly data. First, the categories established in the earlier efforts are utilized. They are reported separately for purposes of consistency. Then, added classifications developed specifically for this study are applied and reported. Section IV presents performance summaries by spacecraft and by major subsystems. It also provides engineering analyses of the anomaly data regarding trends, persistent problem areas, test-related anomalies and other areas of interest. Section V treats the question of measuring on-orbit spacecraft capability over time. It includes consideration of the effect of anomalies on (1) the basic spacecraft, (2) its scientific or applications payload, and (3) its overall mission objectives. A methodology for possible future application is suggested. Three appendices provide (1) an indication of the adequacy of the data base coverage for this update, (2) basic anomaly data tabulations including anomaly codes for purposes of classification, and (3) detailed spacecraft and subsystem performance summaries in graphical form.

II. DATA BASE

This report documents a continuing examination of spacecraft on-orbit reliability that PRC began in 1966. Four earlier studies collected and analyzed data on 350 spacecraft from 52 space programs. Results from these four studies are integrated and reported in Reference 15.

This present study is a contractually limited update to Reference 15. It covers only GSFC and JPL spacecraft which were operational between 1977 and 1982. Several of the analyses integral to the earlier studies are missing here, notably those relating to failure rates and probabilities of failure during launch. Furthermore, no systematic effort has been devoted to reporting the totality of the earlier data here or to relating the earlier study results to those found in this update. Selected comparisons have been made, but if the reader is interested in the entire collection of data and information contained in the PRC space data bank it is necessary to have both Reference 15 and this report.

A. General

In addition to the published reports, an unpublished file of engineering analysis reports (EARs) are maintained for each spacecraft in the data base. The ERAs are maintained at NASA and at PRC.(1)

The EARs are the basic data collection. They contain:

- General descriptive and operational data on each spacecraft.
- A detailed breakdown of the spacecraft assemblies, components, and piece parts.

(1) The NASA contact is Edward Shockey, GSFC Code 302, Telephone (301) 344-5628. The PRC contact is Charles Bloomquist, PRC Systems Services, 10960 Wilshire Boulevard, Suite 2320, Los Angeles, California 90024. Telephone (213) 477-8278.

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- Operating (and dormant) time accumulated by each hardware element.
- Descriptions of all anomalies and failures recorded against the spacecraft, together with information on the known or probable causes of many anomalies.
- Background information regarding manufacture, test, and launch.

The information contained in each EAR, as summarized above, is organized into three categories, namely, (1) general information, (2) reliability data, and (3) development and prelaunch information. General information includes launch data, launch vehicle, launch site, intended mission, orbital parameters, spacecraft description, and a general performance assessment over the time period covered by the data bank.

The reliability data elements, to the extent possible, break the spacecraft down into its major components (receivers, tape recorders, digital decoders, etc.), accumulate the survival hours in space for each (including length of time on standby and number of times cycled), give in a further breakdown the piece parts in each component, and finally, provide a rather detailed description of each anomaly recorded during the mission.

Development and prelaunch information includes, as available, the prelaunch test and checkout routines and experience, and brief descriptions of developmental testing, part selection procedures, and quality assurance provisions.

The subject study is an exception in that it correlates specific anomalies with particular spacecraft; previously published reports and papers do not. This correlation is always possible, however, by returning to the EARs.

The same data collection and reduction procedures and reporting formats are used in each study, including the current one. This uniformity allows ready combination of the data herein with any or all of the previous data sets.

B. Update For This Study

Exhibit 1 depicts the five on-orbit reliability studies, including the current one, in terms of the programs and numbers of spacecraft considered. This update includes 44 spacecraft from 19 programs. Nineteen of these spacecraft were covered in the previous study and continued to operate into this study period. As mentioned previously, access to the total data base (62 programs, 375 spacecraft) requires both this document and Reference 15 since previous data are not, for the most part, repeated here.

As in the previous studies, the basic data sources were the Product Assurance Divisions at the NASA Centers (GSFC and JPL in this study), cognizant spacecraft program offices, and open literature.[1] Of particular help in this update were the Mission Operations Managers for the various Goddard programs.

The two major types of data sought for this study, as in earlier studies, are: (1) an engineering report of the final design of the spacecraft, and (2) a flight analysis for individual spacecraft from which operating histories and all known anomalous behaviors can be obtained. From this information Engineering Analysis Reports (EARs) are generated for each spacecraft. The EAR is tailored to provide the information content required to meet the study objectives and provides a uniform base for each spacecraft of the study.

[1] The EARs contain a complete list of references used, by spacecraft. The number of citations for this update is in excess of 250.

EXHIBIT 1 - CUMULATIVE DATA SAMPLE

Original Study, 1967 (Reference 1)

Program Designation	Number of Spacecraft
Agena	93
ANNA	2
Ariel	2
Courier	2
Early Bird	1
Echo	1
Gemini	8
GEOS	1
IMP	2
Injun	3
Lofti	2
NIMBUS	1
Mariner	4
Mercury	25
OAO	1
OGO	2
Oscar	4
OSO	3
OV-1	3
Pioneer	2
Ranger	9
Relay	1
Sector	2
Snapshot	1
Solrad	1
Syncom	3
Telstar	2
TIROS	8
TRAAC	1
TRANSIT-Oscar 04	17
Vanguard	11
Vela	6

TOTAL: 32 Programs
225 Spacecraft

1971 Update (Reference 7)

Program Designation	Number of Spacecraft
ATS	5
EGRS	13
ESSA	7
Explorer 32	1
GEOS (1)	2
IMP	4
Mariner	3
NIMBUS	4
OAO	2
OGO (1)	6
OSO (1)	5
OV1	9
OV2	2
OV3	6
OV4	2
OV5	3
Pioneer (1)	5
RAE	1
Solrad	2
Vela (1)	4

TOTAL: 20 Programs
86 Spacecraft
9 New Programs
79 New Spacecraft

1972 Update (Reference 9)

Program Designation	Number of Spacecraft
ESSA/TOS (1)	6
IMP (1)	3
NIMBUS (1)	2
NOAA/ITOS	3
OAO (1)	1
OGO (1)	5
OSG (1)	4
RAE (1)	1

TOTAL: 8 Programs
25 Spacecraft
1 New Program
6 New Spacecraft

1978 Update (Reference 15)

Program Designation	Number of Spacecraft
AE	2
ATS (1)	3
GEOS	1
Hawkeye	1
HEAO	1
IMP	3
LANDSAT	2
Mariner	3
MTS	1
NIMBUS (1)	3
NOAA (ITOS)	5
OSO (1)	2
Pioneer	2
RAE	1
SAS	3
SERT	2
SMS/GOES	4
Solrad (1)	1
SSS	1
Viking (2)	4

TOTAL: 20 Programs
45 Spacecraft
10 New Programs
40 New Spacecraft

Current Study

Program Designation	Number of Spacecraft
AE	1
AEM (HCCM & SAGE)	2
ATS (1)	4
DE	2
GOES (1)	5
IMP (1)	1
ISEE	3
IUE	1
LANDSAT (1)	3
MAGSAT	1
NIMBUS (1)	4
NOAA (1)	5
SEASAT	1
SME	1
SMS (1)	2
SMM	1
TIROS N	1
VIKING (1), (2)	4
VOYAGER	2

TOTAL: 19 Programs
44 Spacecraft
10 New Programs
25 New Spacecraft

(1) Includes update(s) of spacecraft analyzed in previous data bank studies.
(2) Viking Program includes 2 Orbiters and 2 Landers.

In the EARs the treatment of standby and redundant units is consistent for all data samples and emphasizes the utilization of only known values. Operational hours in the EARs were recorded as "powered" and "unpowered" where such information was known. For much of the equipment, however, the information available only indicates that at a given time the equipment was known to be operational. For this reason the nominal unit of measure in this report is survival time.

The authors believe that the crux of studies of this nature is the provision of a large amount of data in a readily usable form. For this reason, as well as the fact that the information from the documentation does not warrant application of highly sophisticated techniques, the methods of analysis are simple and straightforward.

Classification and summarization, using simple, readable tables, are the primary presentation techniques. In general, statistical inferences are not drawn from these efforts. Conclusions have been drawn where appropriate, but the emphasis is placed on presenting data in such a form that readers may easily draw their own conclusions in areas of their special interest.

Documentation for the spacecraft in this study was generally of sufficient detail and of high quality. Appendix A indicates the quality of data bank coverage for each spacecraft in the update as a function of the four major tables in the Engineering Analysis Reports.

C. Baseline Data

Exhibit 2 provides a complete list of spacecraft in the update, together with several key data elements. The first four items, space-

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EXHIBIT 2 - SPACECRAFT BASELINE DATA

SPACECRAFT DESIGNATION	LAUNCH DATE, STATUS, STATUS DATE	DESIGN LIFE, OPERATING LIFE (Months)	SYNOPSIS OF HERITAGE/MATURITY	SYNOPSIS OF COMPLEXITY FACTORS	RELATIVE COMPLEXITY RATING
ATMOSPHERE EXPLORER, AE-5	11/20/75 Reentered 6/10/81	12 67	Identical to AE-D except for payload. First spacecraft to use a central computer and data base.	Twelve straightforward scientific instruments. Three axis stabilization with wheels and magnetic torquers. Hydrazine orbit adjust; straightforward telemetry; command and power subsystem. Has a solar pointing platform.	16
APPLICATIONS EXPLORER MISSION, AEM-A (HEAT CAPACITY MAPPING MISSION), (HCCM)	4/27/78 Deactivated 9/30/80	12 29	First in a series of low cost modular spacecraft. Built by Boeing. Based on a spacecraft built for USAF. Magnetic acquisition and in-orbit control had never been attempted before. Radiometer was a modified NIMBUS-5 unit.	Spin stabilized; used magnetic control loop for both acquisition and in-orbit control; had wheels and hydrazine orbit adjust system. No tape recorder. Straightforward telemetry, command, and power subsystems. Had three deployables and one payload instrument.	13
AEM-B (STRATOSPHERIC) AEROSOL AND GAS EXPERIMENT, SAGE)	2/18/79 Failed 1/7/82	12 35	Same basic spacecraft as HCCM but had two tape recorders instead of orbit adjust system: Radiometer was similar to SAM II on NIMBUS-7.	Same as HCCM except for tape recorders and orbit adjust system difference.	13
APPLICATIONS TECHNOLOGY SATELLITE ATS-1	12/7/66 Partially Operational 12/82	36 193	Some outgrowth from the Syncom program, but due to the technological evaluation nature of the ATS program, spacecraft hardware primarily involved new developments.	Extensive communications subsystems, electronically despun antenna utilizing considerable circuitry; straightforward telemetry, command, power; sophisticated applications payload; spin stabilized; straightforward propulsion; had apogee boost engine.	25
ATS-3	11/5/67 Partially Operational 8/1/82	36 182	Same as ATS-1	Basic spacecraft same as ATS-1 except ATS-3 has mechanically instead of electronically despun antenna; increasing complexity very slightly; has somewhat different payload from ATS-1 but equally sophisticated.	27
ATS-5	8/12/69 Partially Operational 12/80	36 161	Same as ATS-1	Same comments as ATS-1 and-3 except ATS-5 was gravity gradient stabilized and therefore did not need a despun antenna or spin control propulsion; did require deployable gravity gradient booms.	27
ATS-6	5/30/74 Deactivated 8/3/79	24 62	New program-many "firsts", e.g., 30-foot reflector, stringent ACS requirements, heat pipes, etc. Little "heritage."	Stringent three-axis control requirements; deployable reflectors and solar arrays; complex-extensive communications systems; on-board computer with plated wire memory. One of the most complex unmanned spacecraft ever flown.	85
DYNAMIC EXPLORER DE-1	8/3/81 Operational 7/31/82	18 12	Outgrowth of the AE's. NASA-standard tape recorders and transponder. Analog/digital multiplexing based on TIROS-N design. Sun sensor same as on RCA Satcom's.	Spin stabilized; two booms; tape recorders, magnetic torquers. No wheels, no propulsion. Straightforward telemetry, command, power and communications. Has microprocessor, two tape recorders. Has six straightforward scientific instruments; 200 meter tip-to-tip antennas.	12
DE-2	8/3/81 Operational 7/31/82	18 12	Outgrowth of the AE's. NASA-standard tape recorders and transponders. Sun sensor similar to IUE's. Analog/digital multiplexing based on TIROS-N design.	Three-axis stabilized; uses wheels and torquers. Command system rather complex because many functions implemented. Straightforward power system and communications. Has microprocessor, two tape recorders, scan platform and magnetometer boom. No propulsion. Fairly straightforward scientific instruments (nine). Has two long extendable antenna booms.	21

EXH[illegible] - SP[illegible]AFT N[illegible] DAT[illegible]

SPACECRAFT DESIGNATION	LAUNCH DATE, STATUS, STATUS DATE	DESIGN LIFE (Months)	OPERATING LIFE (Months)	SYNOPSIS OF HERITAGE/MATURITY	SYNOPSIS OF COMPLEXITY FACTORS	RELATIVE COMPLEXITY RATING
GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES						
GOES-1	10/16/75 Standby 9/12/80	36	59	The SMS/GOES hardware utilized technology and designs developed on the ATS 1 through 5 program.	Straightforward basic subsystems; spin stabilized; somewhat complex radiometer. Has apogee boost motor and hydrazine system.	24
GOES-2	6/16/77 Partially Operational 4/30/82	36	58	Same as GOES-1	Same as GOES-1	24
GOES-3	6/16/78 Standby 3/81	36	33	Third spacecraft in the Ford Aerospace-GOES series.	Has Apogee Boost Motor, hydrazine system, electronically despun antenna. Straightforward command, telemetry, communications and power. Fairly complex radiometer. Spin stabilized; hydrazine system. No tape recorders.	24
GOES-4	9/9/80 Operational 7/31/82	84	23	First spacecraft in Hughes Aircraft-GOES series; outgrowth of ATS and other HAC spacecraft. Same spacecraft bus as HAC GMS. Carried new type of radiometer, new S-band equipment; extensive use of microwave integrated circuits and surface acoustic wave (SAW) devices. New telemetry and command design. Used advanced K-7 solar cells.	Spin stabilized; has hydrazine system, apogee boost motor. No tape recorders. Has mechanically despun platform. Array divided into five sections. Complex radiometer. Uses microprocessors for telemetry control. Fairly complex S-band equipment.	30
GOES-5	5/22/81 Operational 7/31/82	84	14	Second in HAC-GOES series; same spacecraft as GOES-4.	Same as GOES-4	30
INTERPLANETARY MONITORING PLATFORM (IMP-8)	10/26/73 Operational 7/31/82	24	105	Based on earlier IMP's/Explorers.	Straightforward Explorer-type spacecraft; spin stabilized; has cold gas system; two deployables; straightforward scientific payload.	11
INTERNATIONAL SUN-EARTH EXPLORER						
ISEE-1	10/22/77 Operational 7/31/82	36	57	Same cold-gas system as IMP's. Same hardware was IUE spares; based on IUE designs.	Has cold-gas system; simple attitude control. Straightforward power system, data handling and communications. Uses microprocessor for command control. Has thirteen rather straightforward scientific instruments; eight deployables.	14
ISEE-2	10/22/77 Operational 7/31/82	36	57	New design, built by the European Space Agency.	Has cold-gas system; simple spin stabilized attitude control. Straightforward power, data handling and communications. Eight experiments; seven deployables.	12
ISEE-3	8/12/78 Operational 7/31/82	36	48	Same as ISEE-1	Same as ISEE-1 except has hydrazine system (orbit adjust) instead of cold-gas.	14
INTERNATIONAL ULTRAVIOLET EXPLORER	1/26/78 Operational 7/31/82	60	54	Gyro-skewing approach to attitude control represents a new development. Panoramic Attitude sensor originally developed for RAE-B. Analog sun sensors identical to those on OAO and ATS. Digital sun sensor similar to that on OAO-C. Spin mode sun sensor similar to the one on HAWKEYE. Reaction wheels identical to yaw wheel on NIMBUS-D. Wheel drive designed especially for IUE. Data Multiplexer based on GSFC standard design. On-board computer has been used on several GSFC missions. Power subsystem supplied by the European Space Agency.	Some observations require that 3-axis stabilization be maintained for up to fourteen hours. Has complex attitude control system to achieve this (gyros, digital and analog sun sensors, spin mode sun sensor, PAS). Has hydrazine system, wheels. Straightforward communications and command subsystems. Complex data handling - has computer, extensive multiplexing. Has Apogee boost motor, heat pipes and two deployables. Complex telescope control/electronics. No tape recorders.	57

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EXHIBIT 2 - SPACECRAFT BASELINE DATA (Continued)

SPACECRAFT DESIGNATION	LAUNCH DATE, STATUS, STATUS DATE	DESIGN LIFE, OPERATING LIFE (Months)	SYNOPSIS OF HERITAGE/MATURITY	SYNOPSIS OF COMPLEXITY FACTORS	RELATIVE COMPLEXITY RATING
LANDSAT-2	1/22/75 Deactivated 7/20/82	12 90	Similar to LANDSAT-1, and based on technology from the NIMBUS program.	Complex command/clock subsystem with memory; complex power and power distribution system; complex ACS with wheels, gyros, Freon and hydrazine system; also magnetic torquer; fairly complex telemetry and communications; complex payload.	65
LANDSAT-3	3/5/78 Operational 7/31/82	36 53	Outgrowth of LANDSAT-1 and -2; uses improved return beam vidicon and multispectral scanner.	Essentially the same as LANDSAT 2.	65
LANDSAT-4	7/16/82 Operational 7/31/82	36 1	Outgrowth of previous LANDSAT's; new Thematic mapper. Intended for shuttle retrieval/refurbishment.	Thematic mapper much more complex than previous MSS's; has no tape recorders, will utilize TDRSS; basic spacecraft is NASA/Fairchild multi-mission bus; has Ku, X- and S-band communications; required pointing accuracy is 0.01°.	67
MAGSAT	10/30/79 Reentered 6/11/80	5 7	Some MAGSAT hardware originally built for SAS-3. At the time, MAGSAT was the most complex spacecraft ever built at APL. Uses NASA-standard transponders. Tape recorder/transponder interface new on MAGSAT. Payload magnetometers an outgrowth of the designs used on the OGO's, also, vector magnetometer an outgrowth of Voyager magnetic fields experiments.	Uses wheels and magnetic torquers; has gyros, microprocessor, extendable trim boom; straightforward power subsystem; has array drives; fairly complex telecommunications system with microprocessors, tape recorders. Fairly complex structure; fairly straightforward payload.	49
NIMBUS-4	4/8/70 Deactivated 4/80	12 120	Image Dissector Camera same as on NIMBUS-3, otherwise payload updated versions of NIMBUS-3 payloads. Had new Versatile Information Processing System; had upgraded ACS.	Three-axis stabilized to one degree. Two-hundred watts of power supplied by two SNAP-19 generators. Two tape recorders. Extensive command and telemetry subsystems. Several deployables. Four new experiments and five upgraded from earlier spacecraft in the series.	59
NIMBUS-5	12/11/72 Partially Operational 7/31/82	12 116	Had first deployable and retractable scanning microwave radiometer; had five new payload instruments; designs based on earlier NIMBUS' basic spacecraft.	Uses wheels, magnetic torquers, and pneumatics has gyros, extensive clock/timing subsystem; has solar array drive; extensive power and information handling subsystems; complex and extensive payload (seven instruments).	74
NIMBUS-6	6/12/75 Partially Operational 7/31/82	12 86	Outgrowth of earlier NIMBUS spacecraft but incorporated improvements in many basic spacecraft subsystems.	Essentially the same as NIMBUS-5 but had nine payload instruments.	75
NIMBUS-7	10/24/78 Operational 7/31/82	12 45	ACS essentially the same as on NIMBUS-6; some changes in the command/clock subsystem from NIMBUS-6. Same VIP as NIMBUS-6; almost all new Flight Data Handling Equipment; same power system design as NIMBUS-6 but different vendors; of the eight payloads, six were new to NIMBUS-7.	Uses wheels, torquers and Freon pneumatics; has solar array drive, gyros; complex command/clock subsystem; straightforward but extensive flight data and VIP's subsystems; straightforward power subsystem; complex and extensive payload (eight instruments).	77

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EXHIBIT 2 - SPACECRAFT BASELINE DATA (Continued)

SPACECRAFT DESIGNATION	LAUNCH DATE, STATUS, STATUS DATE	DESIGN LIFE, OPERATING LIFE (Months)		SYNOPSIS OF HERITAGE/MATURITY	SYNOPSIS OF COMPLEXITY FACTORS	RELATIVE COMPLEXITY RATING
NOAA-4	11/15/74 Deactivated 11/78	24	48	Long heritage in ESSA/TIROS/TOSS series of spacecraft.	Uses wheels and magnetic torquing; has deployable arrays; straightforward power and communications subsystems; straightforward but extensive command/timing subsystem; fairly complex payloads (four).	34
NOAA-5	7/29/76 Deactivated 6/80	24	46	See NOAA 4	Same spacecraft as NOAA 4.	34
NOAA-6	6/27/79 Operational 7/31/82	24	37	First operational spacecraft of the TIROS-N series; essentially same spacecraft as TIROS-N except for a few design changes due to problems identified on TIROS-N	Uses wheels and magnetic torquing; has gyros, solar array drive, hydrazine and nitrogen system; fairly complex power system; has apogee boost motor; straightforward but extensive command, data handling and communications. Moderately complex payload.	61
NOAA-B	5/29/80 Unsuccessful launch -	-	-	------	------	-
NOAA-7	6/23/81 Operational 7/31/82	24	13	Second operational spacecraft of the TIROS-N series.	Same as NOAA-6.	61
SOLAR MAXIMUM MISSION	2/14/80 Failed 1/15/81	24	11	First of the modular spacecraft built for shuttle retrieval and first use of multi-mission spacecraft bus approach. One of the most software-intensive of the unmanned spacecraft. Had first modular power supply ever flown. Most experiments had predecessors on the OSO's.	Uses wheels, magnetic torquers, and a wide variety of sun sensors; has gyros, deployable array; fairly straightforward power system; has steerable antenna, on-board computer, tape recorders; straightforward command, communications, telemetry and scientific payload.	51
SYNCHRONOUS METEOROLOGICAL SATELLITE						
SMS-1	5/17/74 Deactivated 1/29/81	24	80	First of the SMS/GOES series; see GOES-1.	Same as GOES-1.	24
SMS-2	2/6/75 Standby 2/25/82	24	84	Same as GOES-1.	Same as GOES-1.	24
TIROS-N	10/13/78 Failed 2/27/81	24	28	"Protoflight" spacecraft for the third generation of NOAA's; See NOAA 4-7.	Same as NOAA-6.	61
SEASAT	6/26/78 Failed 10/9/78	12	3	Used standard Agena bus equipment for basic spacecraft functions. Payload a new development except scanning multichannel microwave Radiometer same as on NIMBUS-7.	Uses wheels, has hydrazine orbit adjust, rotating solar array. Overall, very straightforward basic spacecraft subsystems. Fairly complex payload with a double-deployment antenna array.	17
SOLAR MESOSPHERE EXPLORER	10/6/81 Operational 12/20/82	24	14	A low budget explorer; all hardware well within the state of the art.	Spin stabilized, uses magnetic torquers; has no propulsion or pyrotechnics equipment. Very simple spacecraft; only unique feature is disk mounted array on booster-end of spacecraft. Straightforward scientific payload.	10

EXHIBIT 2 - SPACECRAFT BASELINE DATA (Continued)

SPACECRAFT DESIGNATION	LAUNCH DATE, STATUS, STATUS DATE	DESIGN LIFE, OPERATING LIFE (Months)		SYNOPSIS OF HERITAGE/MATURITY	SYNOPSIS OF COMPLEXITY FACTORS	RELATIVE COMPLEXITY RATING
VIKING ORBITER 1	8/20/75 Deactivated 7/80	15	58	Outgrowth of earlier JPL Mariner spacecraft; new developments required to accommodate LANDER	Had very extensive communications, telemetry and command equipment; general purpose computer, tape recorders, memories; extensive pyrotechnics and deployments; complex propulsion; fairly straightforward power subsystem.	95
VIKING LANDER 1	8/20/75 Operational 12/2/82	15	87	New development overall; also all individual hardware represented new developments to accomplish Mars landing, sampling and environmental sensing.	Had highly sophisticated payloads; de-orbit and Mars landing equipment; used radioisotope thermoelectric generators; fairly straightforward communications and data handling.	81
VIKING ORBITER 2	9/9/75 Deactivated 7/24/78	15	34	See VIKING ORBITER 1.	SAME AS VIKING ORBITER 1.	95
VIKING LANDER 2	9/9/75 Failed 3/80	15	54	See VIKING LANDER 1.	SAME AS VIKING LANDER 1.	81
VOYAGER 1	9/5/77 Operational 12/82	48	63	Outgrowth of previous JPL spacecraft but required many new developments to support interplanetary mission.	Has three on-board computers; sophisticated scan platform and articulation control; uses radioisotope generators for power; extensive communications equipment for S- and X-band. Has hydrazine system, gyros, extensive command and control system; has separate propulsion module (solid rocket motor) for Jupiter trajectory injection.	100
VOYAGER 2	8/20/77 Operational 12/82	48	64	Same as VOYAGER 1.	SAME AS VOYAGER 1.	100

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craft designation, launch date, spacecraft status and status date, are self-explanatory. The next column gives the design life(1) and the operating life, calculated as the difference between launch and status dates. If the spacecraft is still operational this figure is, of course, only tentative.

The next two columns attempt to place the individual spacecraft in the context of the larger U.S. space program by giving brief synopses of its heritage/maturity and factors determining its relative complexity. Attempts to tabulate such quantitative factors as pointing accuracy, voltage regulation, data rates, etc., were unsuccessful in that for many spacecraft the requisite data points were unavailable and the others required so many qualifications or explanations that the quantitative nature of the entry was effectively obscured. Thus, our reliance on more qualitative factors.

The final column is our attempt, nevertheless, to quantify relative complexity. The numbers were read from Exhibit 3 which, in turn, represents our best engineering judgment of relative spacecraft complexity. Exhibit 3 is the end result of an iterative, assessment process designed to place all 43 spacecraft in the update (which successfully attained orbit) in relation to each other in terms of complexity. The most complex was then assigned a complexity rating of 100 and the least complex a rating of 10, there being in our judgment about an order of magnitude difference in complexity between the SME and the Voyagers.

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(1) Spacecraft design life is a rather nebulous parameter. It sometimes is not specified at all in the documentation available to us; in other cases multiple design lives are referenced. We have, therefore, selected one design life for each spacecraft that seems most reasonable to us on the basis of all available information.

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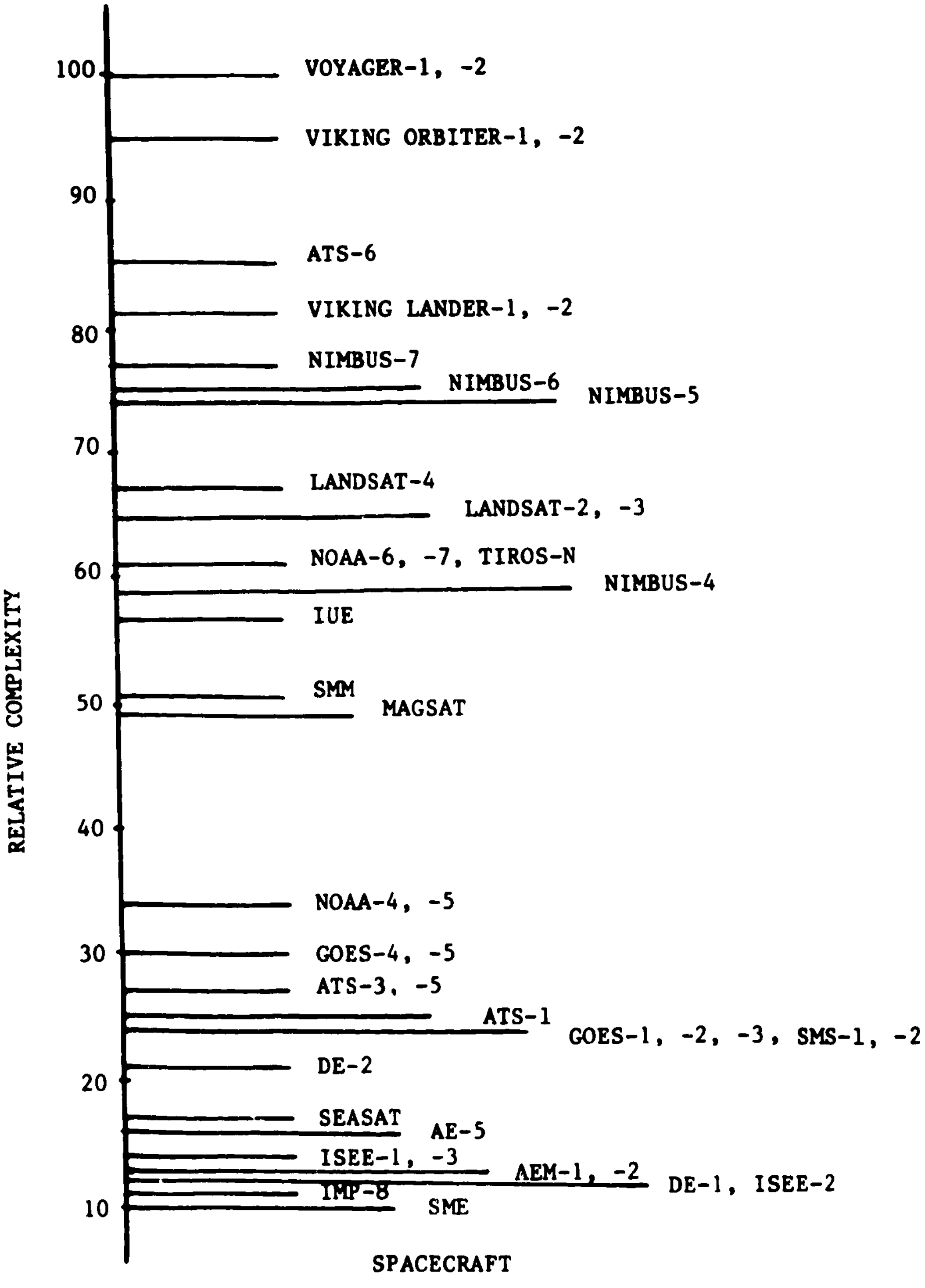

EXHIBIT 3 - RELATIVE SPACECRAFT COMPLEXITY

III. ANOMALY CLASSIFICATIONS

Because of the large number of anomalous incidents in this sample (and in previous samples) classification and summarization procedures are mandatory to extract readily useable information. From the relevant spacecraft EARs, a summary of each anomalous incident in this sample has been prepared. The summary is found in Appendix B-1 in the same format as the corresponding data for the earlier comprehensive studies. Appendix B-1 lists, by spacecraft, every anomalous incident recorded in the EARs subsequent to a successful launch. Each anomalous incident contains the following information:

1. An anomaly index relating the incident, unambiguously, to the information in the EAR.
2. Time the incident occurred. An entry of ϵ indicates that the incident occurred between the end of countdown and the establishment of the initial orbit. An entry of indicates that the anomaly cannot be pinpointed in time since it was intermittent, gradual, or unknown. All other entries are in hours.
3. Three short statements giving a description of the incident, its cause, and its effect on the mission as a whole.
4. Any known corrective action taken to prevent occurrence of the incident on future flights or to obviate its effect on the flight under consideration.
5. Other clarifying remarks required to put the incident in the proper context.

In addition to this summarization, two kinds of anomaly classifications were accomplished: (1) compilations by the classification codes used in all previous studies (the standard approach), and (2) compilations by a set of additional classification codes designed to more fully describe the characteristics of the observed anomalies. Complete compilations are presented in Appendices B-2 and B-3, respectively, in the same order and using the same anomaly index as the summaries of Appendix B-1. The two sets of classifications and their results are discussed in the following subsections.

A. The Standard Approach

In the standard approach, there are nine characteristics for which each anomalous incident is coded. Some of the information needed to select a particular code for a given entry may occur only in the EAR so that, in a sense, the classification codes carry more information than that provided in the entries of Appendix B-1. The complete standard approach coding of each entry is given in Appendix B-2. Unsuccessful launches are not included in these appendices.

Exhibit 4 defines the categories and codes for eight of the classifications used. The ninth classification, Subsystem Function is defined in Subsection III.A.8 below. Definitions of the terms, the results of classifying the 606[1] anomalies of this study and the 2,096[1] anomalies of Reference 15 are given in the following subsections.

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[1] These totals do not include unsuccessful launches.

EXHIBIT 4 - ANOMALOUS INCIDENT CLASSIFICATION CODES, STANDARD APPROACH

I. Mission Subset

- U. Unsuccessful Launch
- S. Spacecraft with No Anomalies Reported
- Spacecraft with Anomalies Reported

II. Mission Term

- L. Long Term
- S. Short Term

III. Mission Phase

- L. Launch and Acquisition
- O. Orbital (Steady-State)
- Q. Unknown

IV. Mission Effect

- 1. Negligible
- 2. Non-Negligible but Small
- 3. 1/3 to 2/3 Mission Loss
- 4. 2/3 to Nearly Total Mission Loss
- 5. Essentially Total Mission Loss
- U. Unknown

V. Spacecraft Subsystem

- a. Timing, Control and Command
- b. Telemetry and Data Handling
- c. Power Supply
- d. Attitude Control and Stabilization
- d* Propulsion
- e. Environmental Control
- f. Structure
- g. Payload (Experimental and Scientific)
- h. Unknown

VI. A. Incident Type

- E. Electrical
- M. Mechanical
- O. Other
- U. Unknown

VI. B. Incident Type

- C. Catastrophic Part Failure
- O. Other Part-Related Incident
- N. Non-Part-Related Incident
- U. Unknown

VII. Incident Cause

- A. Assignable
- N. Non-Assignable
- U. Unknown

Roman numerals following the paragraph headings refer to the Roman numerals in Exhibit 4.

1. Mission Subset (I)

This code simply identifies the unsuccessful launches (U) and those spacecraft for which there are no reported anomalies (S).

For this study, one of the 44 spacecraft launches (NOAA-B) was unsuccessful; there were no spacecraft that experienced zero anomalies. The breakdown by number of spacecraft and percentage is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Mission Subset				
U. Unsuccessful Launch	1	43	2.3	12.3
S. Spacecraft With No Anomalies Reported	0	40	0	11.4
Spacecraft with Anomalies Reported	43	267	97.7	76.3

2. Mission Term (II)

The code identifies long-term (L) or short-term (S) missions. If a mission is anticipated to be longer than 60 days it is classified long-term. All spacecraft in this data sample are long-term missions.

The breakdown, by number of anomalies and percentages, is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Mission Term				
L. Long Term	606	1,695	100	80.9
S. Short Term	0	401	0	19.1

3. Mission Phase (III)

A spacecraft mission can be thought of as consisting of two distinct phases: launch and acquisition (L) and the orbital or steady-state phase (O). An anomaly occurring during launch and acquisition is classified L; if it occurs during steady-state operation it is classified O. A third category, Q, is provided for those instances where the dichotomy cannot be made due to insufficient information. The distinction is made on the best judgment available based on the engineering analysis reports. Generally, those incidents indicating an ϵ, or very few hours of elapsed time at occurrence, are classified as L, all others as O.

The breakdown of anomalies occurring in each category and the associated percentages is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Mission Phase				
L. Launch and Acquisition	61	480	10.1	22.9
O. Orbital (Steady-State)	545	1,608	89.9	76.7
Q. Unknown	0	8	0	0.4

4. Mission Effect (IV)

The five groups included in this classification indicate the severity of the anomalous incident in terms of its effect on the overall mission had it occurred in isolation. The definition of each class 1, 2, 3, 4, and 5 should be self-evident from the classification names given in Exhibit 4. Thus, in column IV of the tables in Appendix B-2 all incidents coded 1 have essentially negligible effect on mission performance; those coded 5 are essentially catastrophic to the mission. The code U indicates there was insufficient information on which to assign a mission effect code.

The breakdown of these groups, by number and percent of anomalies, is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Mission Effect				
1. Negligible	447	1,330	73.8	63.4
2. Non-Negligible but Small	117	579	19.3	27.6
3. 1/3 to 2/3 Mission Loss	32	98	5.3	4.7
4. 2/3 to Nearly Total Mission Loss	5	20	0.8	0.9
5. Essentially Total Mission Loss	4	44	0.7	2.1
U. Unknown	1	25	0.2	1.2

5. Spacecraft Subsystem (V)

Each anomalous incident is coded according to which of eight major spacecraft subsystems is most closely related to the incident.

An unknown category is included for those cases where a relationship does not exist or cannot be determined from the available information. The subsystems used for this classification are meant to define broad functional operations found to one extent or another in all spacecraft. The functional definition for subsystems was chosen rather than a definition based on hardware for two reasons. First, subsystem definitions vary among organizations and among program offices of the same organization. The data analysis requires a grouping that can be applied to all spacecraft of the collective data sample. The second and more important reason for using a functional definition is that, in the predesign stages of future programs, the program management will know what functions the planned spacecraft is expected to perform with more certainty than the actual hardware configuration that will be used to perform the desired functions. The comparisons at the subsystem level as defined in this report would be useful in the predesign phase of program development. For example, one would be interested to know, based on past experience of other programs, with what certainty a spacecraft would deploy its structural elements (structure subsystem) or supply power to the other planned functions (power supply subsystem). In the later stages of development of a projected program, when more is known about the hardware configuration, the interest would shift to the equipment group/component level of analysis which is hardware oriented.

The following list defines the subsystems and indicates the types of equipment that are considered to be a part of each subsystem.

a. <u>Timing, Control and Command</u>

Command receivers, decoders, timers, programmers, sequencers, command distribution equipment

b. <u>Telemetry and Data Handling</u>

Encoders, D/A converters, A/D converters, tape recorders, signal conditioners, telemetry transmitters, tracking transmitters, antennas

c. <u>Power</u>

Batteries, solar arrays, fuel cells, converters, inverters, regulators, protective devices, charge regulators

d. <u>Attitude Control and Stabilization</u>

Gyros, spin control, magnetometers, sun aspect indicators, eddy current dampers, horizon scanners, star trackers, dynamic control

d* <u>Propulsion</u>

Coding this subsystem with a d* indicates that the propulsion subsystem considered here is more closely related to the attitude control subsystem of the spacecraft than to the launch vehicle. Included are hydrazine thrusters, tanks, valves, etc.

e. <u>Environmental Control</u>

Both passive and active thermal control devices, life support systems, etc.

f. <u>Structure</u>

Basic structure, booms, solar paddles, separation.

g. <u>Payload (Experimental and Scientific)</u>

Wide-band communications (for spacecraft where this equipment was considered experimental), microwave equipment (cavities, TWTs, etc., flown for assessment purposes), university experiments, particle detectors, mass spectrometers, plasma analyzers, infrared radiometers, ultraviolet radiometers.

Although it is felt that these groupings are essentially self-explanatory, checking a few of the codes in Appendix B-2 with their corresponding entries in Appendix B-1 should dispel confusion. This procedure is applicable to most of the other classifications as well.

The breakdown, in terms of number of anomalies and their associated percentages, to each of the subsystem categories is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Refernece 15
Spacecraft Subsystem				
a. Timing, Control and Command	55	290	9.1	13.8
b. Telemetry and Data Handling	116	599	19.1	28.6
c. Power Supply	56	199	9.2	9.5
d. Attitude Control and Stabilization	123	287	20.3	13.7
d*. Propulsion	26	62	4.3	2.9
e. Environmental Control	16	36	2.6	1.7
f. Structure	6	47	1.0	2.2
g. Payload (Experimental and Scientific)	208	540	34.3	25.8
h. Unknown	0	36	0	1.7

6. Incident Type (VI)

a. Incident Type (VI.A)

This classification places an anomaly in one of four mutually exclusive groups: electrical (E), mechanical (M), other (O), and unknown (U). Those entries in Appendix B coded with an E in the VI.A column indicate that anomalous behavior is exhibited by electrical or electronic parts, components, subsystems, or functions. Those anomalies coded M are similarly defined for mechanical parts, components, subsystems, or functions. An O indicates behavior of equipment that cannot be classified electrical or mechanical: propellant degradation, for example. A U indicates insufficient information to assign the entry to any of the other three categories.

The breakdown of anomalies and percentages in this classification group is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Incident Type				
E. Electrical	329	1,538	54.3	73.4
M. Mechanical	64	192	10.6	9.2
O. Other	197	158	32.5	7.5
U. Unknown	16	208	2.6	9.9

b. Incident Type (VI.B)

The classification of column VI.B in Appendix B attempts to divide incidents into those that are part related and those that are non-part related. A code of C indicates those incidents arising from a catastrophic part failure.[1] An O indicates that the anomalous incident is related to behavior of a part (or parts) that has not failed catastrophically (degraded, intermittent, etc.). An N indicates an anomalous incident not related to any part misbehavior. A U indicates that insufficient information exists to determine whether part behavior was involved or not.

The breakdown by number and percentage of anomalies for these categories is as follows:

Incident Type	Number: This Study	Number: Reference 15	Percentage: This Study	Percentage: Reference 15
C. Catastrophic Part Failure	21	225	3.5	10.7
O. Other Part-Related Incident	52	242	8.6	11.5
N. Non-Part-Related Incident	277	727	45.7	34.7
U. Unknown	256	902	42.2	43.0

7. Incident Cause (VII)

Three broad groups are defined for incident cause in column VII of the tables in Appendix B: assignable causes (A), non-assignable causes (N), and unknown (U).

An assignable cause is attributed to an anomalous incident if the incident could have been prevented by taking some action well within the

[1]The term "catastrophic" here is defined to mean "catastrophic" to the part and not necessarily to the larger component system. Typical types of catastrophic part failures include a transistor or diode shorting for no known reason. This definition is consistent with that used in the negative exponential distribution for modelling failure probability.

state-of-the-art prior to launch. If the incident could not have been prevented in this manner, it is classified nonassignable (N). If insufficient information exists to make a judgment, the anomaly is classified unknown (U).

The breakdown for these categories is as follows:

	Number		Percent	
	This Study	Reference 15	This Study	Reference 15
Incident Cause				
A. Assignable	251	732	41.4	34.9
N. Non-Assignable	83	264	13.7	12.6
U. Unknown	272	1,100	44.9	52.5

Further discussion of the assignable cause category is given in Subsection III.B, below.

8. Subsystem Function (VIII)

This classification is a secondary breakdown of spacecraft subsystem .

The assignment of anomalies to the subsystems (characteristic V) is helpful in narrowing down the functional aspects of spacecraft which are the most troublesome. A further step in this direction is justified to isolate more precisely the location of anomalous incidents. To do this a number of subfunctions (characteristic VIII) are defined for each previously defined spacecraft subsystem. The subfunctions for each subsystem are defined so that they are mutually exclusive and exhaustive, i.e., they do not overlap and they do cover the entire subsystem. In determining the quantities of the subfunctions and their associated anomalies, only data that specifically identifies the subfunction is considered. For instance, if the data clearly involve a command decoding subfunction, then an assignment is made to that category. Each anomalous incident carries, therefore, two codes relating the incident to functional location within the spacecraft. The subsystems, subfunctions, and codes used for each are tabulated in Exhibits 5 and 6. Exhibit 5 gives the total number of functions in this sample, the total number of anomalies observed, and the anomalies per function for this study. Exhibit 6 presents the same information for data previously available in the PRC data bank and reported in Reference 15.

EXHIBIT 5 - DETAILED CLASSIFICATION OF ANOMALOUS INCIDENTS BY SPACECRAFT SUBSYSTEM AND FUNCTION, THIS STUDY

Subsystem Function	Number of Functions in Sample		Number of Reported Anomalies by Function		Anomalies per Function	
a. TIMING, CONTROL, AND COMMAND	43		55		1.28	
1. Receiving		43		21		0.49
2. Decoding		43		3		0.07
3. Command Distribution		25		17		0.68
4. Sequencing and Programming		27		5		0.19
5. Timing		28		9		0.32
6. Manual Control		-		-		-
7. Unknown		-		-		-
8. Unassignable		-		-		-
b. TELEMETRY AND DATA HANDLING	43		116		2.70	
1. Data Point Sensing and Monitoring		43		13		0.30
2. Signal Conditioning		8		1		0.12
3. Encoding, Formatting		43		2		0.05
4. Data Storage		27		43		1.59
5. Transmission		43		56		1.30
6. Unknown		-		-		-
7. Unassignable		-		-		-
c. POWER	43		56		1.30	
1. Conversion		43		4		0.09
2. Storage		41		3		0.07
3. Power Control		42		45		1.07
4. Power Distribution		17		2		0.12
5. Unknown		-		2		-
6. Unassignable		-		-		-
d. ATTITUDE CONTROL AND STABILIZATION	40		123		3.08	
1. Orientation Sensing		40		90		2.25
2. Active Attitude Correction		22		19		0.86

EXHIBIT 5 - (Continued)

Subsystem Function		Number of Functions in Sample		Number of Reported Anomalies by Function		Anomalies per Function	
	3. Passive Stabilization		8		3		0.38
	4. Unknown		-		1		-
	5. Unassignable		-		10		-
d*.	PROPULSION	37		26		0.70	
	1. Navigation		4		4		1.00
	2. Propulsion		33		22		0.67
	3. Unknown		-		-		-
	4. Unassignable		-		-		-
e.	ENVIRONMENTAL CONTROL	43		16		0.37	
	1. Active Thermal Control		23		15		0.65
	2. Life Support		-		-		-
	3. Unknown		-		-		-
	4. Unassignable		-		1		-
f.	STRUCTURE	43		6		0.14	
	1. Basic Structure		43		5		0.12
	2. Deployable Structure		33		1		0.03
	3. Separation		43		0		0.00
	4. Unknown		-		-		-
	5. Unassignable		-		-		-
g.	PAYLOADS	256		208		0.81	
	1. Scientific		230		205		0.89
	2. Technical		26		1		0.04
	3. Unknown		-		1		-
	4. Unassignable		-		1		-
h.	UNKNOWN	-		-		-	

EXHIBIT 6 - DETAILED CLASSIFICATION OF ANOMALOUS INCIDENTS BY SPACECRAFT SUBSYSTEM AND FUNCTION, REFERENCE 15

Subsystem Function	Number of Functions in Sample		Number of Reported Anomalies by Function		Anomalies per Function	
a. TIMING, CONTROL, AND COMMAND	265		290		1.09	
1. Receiving		261		103		0.39
2. Decoding		251		23		0.092
3. Command Distribution		72		30		0.42
4. Sequencing and Programming		188		63		0.33
5. Timing		133		30		0.22
6. Manual Control		11		--		--
7. Unknown		--		29		--
8. Unassignable		--		12		--
b. TELEMETRY AND DATA HANDLING	277		601		2.17	
1. Data Point Sensing and Monitoring		164		206		1.26
2. Signal Conditioning		46		3		0.065
3. Encoding, Formatting		264		63		0.24
4. Data Storage		126		151		1.20
5. Transmission		270		151		0.56
6. Unknown		--		14		--
7. Unassignable		--		12		--
c. POWER	282		199		0.70	
1. Conversion		175		40		0.23
2. Storage		271		77		0.28
3. Power Control		247		50		0.20
4. Power Distribution		179		12		0.067
5. Unknown		--		18		--
6. Unassignable		--		2		--
d. ATTITUDE CONTROL AND STABILIZATION	244		285		1.17	
1. Orientation Sensing		226		131		0.58
2. Active Attitude Correction		209		250		1.20

EXHIBIT 6 - (Continued)

Subsystem Function	Number of Functions in Sample	Number of Reported Anomalies by Function	Anomalies per Function
3. Passive Stabilization	69	11	0.16
4. Unknown	--	16	--
5. Unassignable	--	8	--
d*. PROPULSION	121	62	0.51
1. Navigation	108	11	0.10
2. Propulsion	121	37	0.30
3. Unknown	--	4	--
4. Unassignable	--	10	--
e. ENVIRONMENTAL CONTROL	80	36	0.45
1. Active Thermal Control	63	24	0.38
2. Life Support	12	13	1.08
3. Unknown	--	2	--
4. Unassignable	--	5	--
f. STRUCTURE	272	47	0.17
1. Basic Structure	267	2	0.0075
2. Deployable Structure	89	33	0.37
3. Separation	256	11	0.043
4. Unknown	--	1	--
5. Unassignable	--	--	--
g. PAYLOADS	809	544	0.67
1. Scientific	711	423	0.59
2. Technical	98	120	1.22
3. Unknown	--	1	--
4. Unassignable	--	--	--
h. UNKNOWN	--	36	--

B. Additional Categories

For this study several additional ways of treating the basic anomaly data were considered. These included additional treatment of anomaly causes, anomaly type, history, test background, level of spacecraft breakdown giving rise to the anomaly, the heritage of anomalous hardware, etc. Many of these considerations are reflected qualitatively in the engineering analysis of Section IV.B. Quantitatively, four characteristics were found to have sufficient information to provide additional useful categorization. These are cause, type, testability, and source. Exhibit 7 defines the categories and codes for these additional classifications. It also provides the number and percentage of the 606 anomalies assigned to each category. Definitions of the terms and notes on classifying the 606 anomalies of this study are given in the following subsections.

Roman numerals following the paragraph headings refer to the Roman numerals in Exhibit 7. A complete tabulation of these codes, by anomaly, is given in Appendix B-2.

1. Anomaly Cause (X)

Anomaly cause is treated in the standard approach but only to the extent of determining if the anomaly has an assignable cause or not. While the previous studies in this series further analyzed the anomalies with assignable causes, no formal coding was reported. This categorization remedies that situation and also defines a new set of "causes" more in keeping with recent data. The first three categories all represent design problems. The first, Space Environment, is invoked when the design provides an inadequate response to the environmental stresses of space.

EXHIBIT 7 - ANOMALOUS INCIDENT CLASSIFICATION CODES, ADDED CHARACTERISTICS

			Number	Percent
X.	Anomaly Cause			
	a.	Space Environment	56	9.2
	b.	On-Board Software	21	3.5
	c.	Design, Other	90	14.9
	d.	Quality Control/Workmanship	25	4.1
	e.	Contamination	21	3.5
	f.	Catastrophic Part Failure	40	6.6
	g.	Catastrophic Circuit Failure	25	4.1
	h.	Catastrophic Component Failure	28	4.6
	i	Catastrophic Black Box Failure	33	5.4
	j	Unknown	267	44.1
		TOTAL	606	100.0
XI.	Anomaly Type			
	S.	Systematic	216	35.6
	W.	Wearout/Aging/Depletion	44	7.3
	C.	Chance	20	3.3
	G.	Glitch	52	8.6
	U.	Unknown	274	45.2
		TOTAL	606	100.0
XII.	Testability			
	Y.	Yes	95	15.7
	N.	No	90	14.9
	M.	Maybe	116	19.1
	U.	Unknown	305	50.3
		TOTAL	606	100.0
XIII.	Source			
	1.	Part	68	11.2
	2.	Circuit/Subassembly	66	10.9
	3.	Component	117	19.3
	4.	Black Box	97	16.0
	5.	Subsystem/Interface	15	2.5
	6.	Interaction	153	25.2
	7.	Unknown	90	14.9
		TOTAL	606	100.0

The second, On-Board Software, covers anomalous behavior attributable to errors in software or to software which is inadequate for actual operational procedures. The third category, Design, Other, covers all other anomalies attributed to design deficiencies. Anomalies are categorized as Quality/ Workmanship if, and only if, the source documentation so specifies. Thus, there may be more of these anomalies than appear in the Exhibit 7 tabulation. Contamination includes all reports of any kind of foreign matter in or on the spacecraft hardware. Catastrophic failure occurs when a particular level of hardware (Part, Circuit, Component, Black Box) fails completely for none of the previously listed causes. Parts are single integrated circuits, valves, motors, etc. Circuits are actual electrical circuits (oscillators, amplifiers, etc.) or small collections of parts (gear assemblies, for example). Components are sets of "stand-alone" hardware, typically: tape drives, power converters, gyro electronics. Black Boxes are complete functional units, e.g., tape recorders, batteries, solar arrays, or command decoders. The Unknown category is reserved for those anomalies for which there is insufficient information to make any other assignment.

2. Anomaly Type (XI)

The standard approach treats anomaly type in two dimensions. The first distinguishes between electrical, mechanical, or other (chemical, etc.) type of anomaly and the second the relationship of the anomaly to piece part behavior. This categorization examines whether the anomalies are deterministic or not. Thus, the category Systematic includes anomalies that would recur if identical hardware were operated under identical conditions. Wearout, Aging, and Depletion are special cases of systematic anomalies and have been broken out separately. Two kinds of "random" anomalies have also been included. The first, Chance, represents significant anomalies that would not necessarily occur if identical hardware were operated under identical conditions. These anomalies are almost always reported in the source documentation as random failures. Glitches are also randomly occuring anomalies. They are usually insignificant in terms of mission effect, occur at most a very few times then disappear requiring no corrective action other than perhaps a command to restore proper status. Again, nearly half of the anomalies cannot be assigned to the above categories.

3. Testability (XII)

This categorization answers the question, "Could prelaunch testing have revealed the anomaly?" A "Yes" was assigned if it was reasonably clear that some type of testing would have produced the anomaly. A "Yes" was not assigned if the required testing was beyond a reasonable definition of the state of the art or would have required testing of excessive duration. A "No" was assigned if no test would have a reasonable expectation of producing the anomaly (a random part failure, for example). A "No" was also assigned if a test could be conceived but was clearly impractical (requiring zero gravity, for example) or would have been prohibitively expensive. An assignment of "Maybe" covers the situation in which test expense or sophistication while not clearly out of the question are approaching that situation. This category is also assignned when a clear distinction between "Yes" and "No" is not possible based on available data. The "Unknown" category represents the case where there is not enough information available to make any other assignment.

4. <u>Source</u> (XIII)

This classification has been constructed to reveal where the anomalies originate. The first four categories are simply hardware items of increasing levels of complexity. The hardware levels are defined as in the Anomaly Cause classification. In each case, the lowest applicable level was assigned that the available information would support. A few anomalies could not be isolated below the Subsystem/Interface level. These are mostly incorrect wiring harnesses. A much more frequently occurring source is "Interaction." This covers all anomalies where incorrect responses occur between groups of hardware or between the hardware and its operating environment. Typical anomalies in this category are wheel unloading when the tape recorder stops, RFI, turn-on transients, and contamination of one set of hardware due to outgassing from another. The "Unknown" category is assigned where insufficient information is available to make any other assignment.

IV. ANALYSIS

For this study, two types of analyses of the basic anomaly and spacecraft survival data were conducted. The first deals with spacecraft and spacecraft subsystem performance over their observed lifetimes. The second is an engineering analysis of several special factors.

A. Performance Summaries

The performance of each spacecraft considered in this update is indicated on a separate bar chart in Appendix C-1. The survival time for each subsystem (as defined in the documentation for that spacecraft) is presented as are the survival times for all anomalous components. Survival times are also indicated for the redundant units of anomalous components whether or not they themselves had anomalies. Each and every anomoly is charted at the time it occurred and against the component or subsystem in which it occurred. A distinction is made on the charts between failing components (totally unusable) and less serious anomalies.

For those spacecraft that were considered in previous studies, all anomalies from launch have been included even though these anomalies do not otherwise form part of the update data base. They are treated in Reference 15.

A second set of charts indicates the performance of major spacecraft subsystems. These are collected in Apendix C-2. Since each spacecraft has a somewhat different breakout of subsystems, we have standardized on the eight defined in subsection III.A.5. For the major subsystems (Timing, Control and Command; Telemetry and Data Handling; Power Supply; Attitude Control and Stabilization, and Payload) an entry is made for each spacecraft whether or not it had significant anomalies in the subject subsystem. If it had significant anomalies, the anomalous components (and their redundant units, if any) are also listed. The Structure subsystem does not appear since there were no significant anomalies in this subsystem in this update. Since so few anomalies occurred in the Propulsion and the Environmental Control subsystems, only those spacecraft are listed which suffered significant anomalies in these areas.

In addition to being ordered by subsystem rather than spacecraft, this set of charts differs from the spacecraft charts in two ways. First, only "significant" anomalies are included. These are generally those categorized as having a mission effect code of 2 or greater (see subsection III.A.4) although all anomalies in redundant units, whose mission effect is negligible because of the redundancy, are also included. The second major difference is that time, rather than being plotted in hours, is plotted in units of spacecraft design life. Thus, an operating time of 67 months for an AE-5 subsystem is plotted as 67/12 = 5.6 since its design life is one year (see Exhibit 2). Similarly, an operating time of 62 months for an ATS-6 subsystem is plotted as 62/24 = 2.6 since the ATS-6 design life is two years.

B. Engineering Analyses

Engineering analyses were conducted to provide further insights into the nature of the anomalies that have occurred on the satellites in this update. The analyses covered seven areas ranging from persistent problems and test-related anomalies to black box failures and RFI/EMI. Each of the seven areas is discussed below in a separate subsection.

1. Persistent Problems

In an earlier analysis of the data bank, it was found that over 80 percent of all anomalies fell into 30 categories of leading problem areas (Reference 14). It was also noted that these categories represented "persistent" problems in that the anomalies occurring on the more recently launched spacecraft were of the same types as the anomalies on earlier spacecraft. Since a significant amount of new data were collected on this data bank update, it was deemed desirable to reexamine these persistency trends.

Once again it was found that approximately 80 percent of the anomalies "fit" the 30 problem areas. Exhibit 8 depicts the rank order of these problem areas for this update, for the 1978 update and for the pre-1978 data bank. The three-part exhibit illustrates the persistency of the problem areas over time as well as the shifts in their ranks.

A number of interesting observations can be made from the exhibit. For example, as time passes fewer problem areas account for 50 percent of the anomalies. This implies that by addressing the five upper-ranking problem areas in this update one would in fact be addressing forty percent of the observed anomalies. In the pre-1978 era, nine problems would have had to be addressed to achieve similar coverage.

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EXHIBIT 8 - RANK ORDER OF PROBLEM AREAS

(Note: Ranking is in descending order by number of anomalies, i.e., #1 had the most anomalies)

PRE-1978 UPDATE

1. Scientific Instruments
2. Tape Recorders
3. Camera Equipment
4. Batteries
5. RFI/EMI
6. Command & Control (Logic)
7. Telemetry, RF
8. Power Conditioning
9. Spurious Commands
10. Telemetry Encoding
11. Command & Control (Timers, Sequencers)
12. Command, RF-Lock On
13. Command & Control (Registers, Memories)
14. (1) Star Trackers / Sun Sensors / Telemetry Sensing / Wideband Transmitters
15. Reaction Wheels / Propulsion (Chemical)
16. Command, RF - Other (2)
17. Thermal Control
18. Deployable Structures
19. Horizon Sensors
20. Wideband, Other (3)
21. Solar Array Degradation
22. Solar Array, Other (4)
23. Gyros
24. Solar Array Drives
25. Wideband Receivers
26. Wideband Transponders

1978 UPDATE

1. Scientific Instruments
2. RFI/EMI
3. Tape Recorders
4. Camera Equipment
5. Propulsion (Chemical)
6. Batteries / Star Trackers
7. Wideband Transmitters
8. Deployable Structures
9. Telemetry Sensing
10. Solar Array, Other (4)
11. Telemetry, RF / Command & Control (Timers, Sequencers)
12. Sun Sensors
13. Power Conditioning
14. Command & Control (Logic)
15. Telemetry Encoding
16. Spurious Commands / Command & Control (Registers, Memories)
17. Wideband, Other (3)
18. Thermal Control
19. Wideband Transponders
20. Command, RF-Lock On / Reaction Wheels
21. Wideband Receivers
22. Horizon Sensors
23. Gyros
24. Solar Array Drives / Solar Array Degradation
25. Command, RF-Other (2)

Median (5)

THIS UPDATE

1. Scientific Instruments
2. Propulsion (Chemical)
3. RFI/EMI
4. Telemetry Sensing
5. Tape Recorders
6. Thermal Control
7. Batteries / Command & Control (Logic)
8. Gyros / Command & Control (Registers, Memories)
9. Deployable Structures
10. Telemetry Encoding / Wideband Transmitters
11. Solar Array, Other (4) / Command & Control (Timers, Sequencers) / Power Conditioning
12. Horizon Sensors / Sun Sensors
13. Spurious Commands / Camera Equipment
14. Reaction Wheels / Star Trackers
15. Solar Array Degradation / Command, RF-Lock On / Wideband Receivers / Wideband Transponders
16. Command, RF-Other (2) / Telemetry, RF / Wideband, Other (3)
17. Solar Array Drives

NOTES:
(1) Brackets indicate a "tie" for the bracketed rank
(2) Other than Command, RF-Lock On
(3) Other than Wideband receivers, transmitters, and transponders
(4) Other than Array degradation
(5) Dashed line indicates the "median," i.e., the categories above and below the line each represent approximately half of the total anomaly count.

The rank of tape recorders as a problem area has dropped steadily from the first sample to the last while remaining a significant problem area. Note that this drop in rank could mean either that tape recorders are getting better or other problems are getting worse. RFI/EMI also continues to be a significant problem.

Chemical propulsion now ranks second only to scientific instruments as a problem area. It's ranking in the pre-1978 sample was 15 and in the 1978 sample it was 5. Part of the reason for the rank increase in this study is the large number of propulsion problems on ATS-6. However, many other spacecraft suffered from 1 to 3 propulsion problems, indicating that anomalous behavior in chemical propulsion systems is a general and increasingly severe problem. Another interesting increase is observed in the gyro category. The ranks are 23, 23, 8 from the earliest to the most recent sample. This is due in part to several gyro problems on IUE, TIROS-N, and NOAA-6 but again it seems to be a more general problem as well and a definite cause for concern.

The RF Telemetry category ranking dropped from 7 to 11 to 16 in the most recent sample. A major reason for this is that spacecraft now rely extensively on S-band equipment for telemetry, and S-band anomalies are included in the Wideband categories.

2. Test-Related Anomalies

Anomalies in the update sample were classified according to whether they might have been eliminated through some type of testing (See Section III.B). Anomalies known to be related in some fashion to the testing program were also identified. Twenty seven such anomalies were found and although there are undoubtedly others, specific information is available only for these 27.

Seven anomalous incidents were reported that were known to exist as anomalies prior to launch. One typical anomaly of this type involved a memory halt on LANDSAT-3 when an S-band timer reset was commanded. This abnormal response had occurred occasionally prior to launch. On SEASAT, a 21 GH_z electrical temperature monitor was reported as failed prior to launch, then returned to normal operation, but failed again about 300 hours into the mission. Another typical anomaly involves payload data interference over the South Atlantic Anomaly on NIMBUS-7; this was expected due to the type of data channel detectors utilized.

Ten anomalies were of a type noted prior to launch but not then considered to be an anomaly. For instance, on NOAA-6 a ceramic capacitor had been identified as a problem component before launch, and was replaced with specially screened items. Nevertheless, problems with this capacitor recurred and caused significant losses of instrument data. In another case, a tape recorder on SME did not respond to playback commands when the unit was cold; symptoms of this anomaly had been noted in prelaunch tests

Two anomalies -- both on NIMBUS 7 -- were specifically reported as having not been revealed in testing. One of these involved interference with the scanning of one instrument by the scanning of another instrument. It was reported that this was possibly due to structural resonance or structural transmission, and that the test fixture could have masked structural effects. The other anomaly of this kind involved unexpectedly high temperatures of the cooler door and cone on the Coastal Zone Color Scanner. It was reported that this possibly occurred because of higher earth albedo in orbit than was simulated in thermal-vacuum testing.

Four anomalies existed prior to launch but went undetected, including a wiring error in a thruster control harness on AE-5. Four anomalies were reported that involved settings or procedures based on test data that were later found to be inadequate. For instance, on Viking Lander 2 battery temperatures increased significantly higher than predicted. It was reported that the temperature predictive model was based on data from preproduction, prototype batteries rather than flight batteries, and was in error.

3. Environmental Effects

Of the 606 update anomalies, 56 (or slightly over 9 percent) were caused by some type of environmental effect. Since this is a rather significant proportion of the anomalies, and particularly since many of these anomalies could possibly have been prevented by more adequate design or testing provisions, the anomalies were further investigated in terms of hardware and functional areas.

In this investigation, environmental effects were broadly defined as those originating external to the spacecraft itself. It was found that ten categories encompassed these effects:

(1) Effects of orbit: Determined by orbital characteristics such as eclipse and solstice, sun angle, day/night and night/day transitions, orbital location, etc.

(2) Temperature effects: Created by the space thermal environment and the reactions of the spacecraft to this environment.

(3) Sun effects: Resulted from the sun's visible spectrum.

(4) Moon effects: Resulted from lunar gravitation and reflected light.

(5) Atmospheric noise: Associated with the atmospheric RF spectrum.

(6) Effects of vacuum: Associated with the space vacuum.

(7) Earth effects: Resulted from albedo and the earth's magnetic field.

(8) Radiation effects: Associated with space radiation.

(9) Effects of launch: Created by the launch environment.

(10) Other: Environmental effects not encompassed by the other categories.

From the above, it can be seen that "overlap" between the categories can occur. For instance, an excessive spacecraft temperature might be due to either the space thermal environment or the sun angle as determined by the spacecraft's orbital characteristics. In assigning anomalies to the environmental effects categories in this investigation, such possible overlaps were handled by basing the assignment on the primary environmental effect leading to the the anomaly as given in the data. That is, if the primary cause of spacecraft overheating was the sun angle, the anomaly was assigned to the orbital effects category rather than the temperature effects category. It is felt that assigning the anomalies in this manner provides a clearer indication of where more emphasis would be warranted during design and test.

Exhibit 9 depicts in matrix format the distribution of anomalies by hardware/functional area and the various environmental effects leading to them. Typical examples of anomalies assigned to each category are as follows:

(1) In the "Effects of Orbit" category, anomalies include the GOES-4 loss of RF power from a UHF transmitter pre- and post-eclipse, and the MAGSAT anomaly involving sun interference in the star camera in the Southern hemisphere. Another example is the array "notching" that occurred on NIMBUS-7 at night/day transitions.

(2) In the "Temperature Effects" category, anomalies include the deployment problem on SAGE attributed to a stiff cable due to low temperature. Also, the ATS-6 parabolic reflector antenna anomaly consisting of distortions due to diurnal thermal gradients was assigned to this category.

(3) In the "Sun Effects" category, three of the anomalies involve abnormal operation of horizon scanners/earth sensors due to sun interference (SAGE, NOAA-7 and SEASAT). This category also includes erratic operation of NIMBUS-7 sun sensor at some sun angles.

(4) All of the anomalies attributed to "Moon Effects" are associated with lunar illumination. Twice it interfered with earth sensor operation (GOES-3 and TIROS-N); it also interfered with the operation of a radiometer on TIROS-N.

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EXHIBIT 9 - ANOMALIES ATTRIBUTED TO ENVIRONMENTAL EFFECTS

Spacecraft Hardware/Function Incurring Anomaly	Environmental Effect: Effects of Orbit	Temperature Effects	Sun Effects	Moon Effects	Atmospheric Noise	Effects of Vacuum	Earth Effects	Radiation Effects	Launch Effects	Other	TOTAL
Arrays	2							3			5
Clocks					2			1			3
Command Receivers					2						2
Computers/Microprocessors								1	1		2
Deployables		1									1
Gyro electronics								1			1
Heat Pipes								1			1
Horizon Scanners/Earth Sensors		1	3	2			1				7
Memories								1			1
Meteorological Payloads, Radiometers			1	2		1		1			5
Meteorological Payloads, Non-Radiometers	1				2	2	1				5
Propulsion						1			1		2
Reflectors (Antennas)		1					1			1	1
Scientific Instruments	1					1		1		2	3
Spacecraft/System Level		1				1		1			5
Star Trackers/Star Cameras	1						1		1		3
Sun Sensors/Solar Aspect Sensors	2		1						1		4
Thermal Control					1						1
Transmitters, S-band											1
Transmitters, UHF	1										1
TOTAL	8	4	5	4	7	6	4	11	3	4	56

(5) At least two of the anomalies designated "Atmospheric Noise" were associated with the South Atlantic Anomaly; when the respective spacecraft were over this location, RFI caused a clock jump on SMM and interfered with a payload instrument on NIMBUS-7. LANDSAT-3 also experienced RFI over magnetic anomalies, although the data does not specify which ones. Also assigned to this category was a TIROS-N anomaly involving spurious command verifications; this was attributed to the receiver's frequency being in the neighborhood of amateur radio and television traffic.

(6) Two of the anomalies assigned to "Effects of Vacuum" were caused by outgassing (LANDSAT 3 and Voyager 2). A third anomaly -- the star tracker on Voyager 2 tracking bright particles just after launch -- was also judged to be due to outgassing.

(7) In the "Earth Effects" category, one of the anomalies includes a spectrometer on SME breaking-limits due to the effects of a "bright earth." On SEASAT, a horizon scanner tracked cold clouds, and on SMM earth albedo entered a sun sensor's field of view.

(8) "Radiation Effects" includes three instances of array damage, one due to a large solar flare (ATS-6) and two due to the same large solar particle event (GOES-4 and GOES-5). Three other anomalies involve Jovian radiation effects on the Voyagers. Also, a radiation "hit" on DE-1 wiped out a microprocessor chip.

(9) Three anomalies were caused by the "Effects of Launch". On MAGSAT, there were indications that a thermal panel came off during launch. On TIROS-N, propulsion problems were attributed to a nut relaxing due to launch shock. On Voyager 2, a computer became "confused" by the high boost rates and issued commands to counteract them.

(10) Four anomalies were assigned to the "Other" category. On ATS-6, intermittent array thermistor operation was attributed cryptically to "the long term effects of cycling in orbit." The detector window of a scientific instrument on ISEE-3 was punctured by a micrometeorite. NOAA-7 experienced higher solar pressure torques than expected, and the Viking Orbiter 1 experienced a strong gravity gradient torque at periapsis.

4. <u>Black Box Failures</u>

As is evident from discussions elsewhere in this report, a large number of data bank anomalies involve intermittents (some of which "go away"), degraded performance that does not significantly impact the mission, or other types of anomalous behaviors that do not render the associated hardware useless. It seemed, therefore, that it would be of interest to identify and tabulate the anomalies where a significant piece of hardware became useless due to some type of problem.

These "significant pieces of hardware" are referred to herein as "black boxes," and include batteries, tape recorders, gyros, receivers, radiometers, and the like. The black boxes are generally elements of the basic spacecraft subsystems; experiments were specifically excluded from consideration in this analysis.

The data were then searched to identify those anomalies associated with the failures of black boxes. The definition of "failure" was that the black box was rendered useless by the anomaly. In some cases, this implies that the black box ceased to function; in others that the anomaly caused such degraded or erratic operation that the black box could not provide its intended function.

In the update sample, 65 such black box failures were found representing approximately 11% of all anomalies. The failures occurred on 17 types of black boxes. These data are depicted in Exhibit 10.

The quantities shown in the left-most column indicate the number of black box failures where redundancy was both provided and operable. In the next column, the number of failures shown are those where redundancy was provided but had previously failed The next column indicates the number of failures where no redundancy had been provided.

For batteries, only the total number of failures is shown; that is, the failures are not broken down to indicate redundancy provisions. This was done because batteries are seldom truly redundant since a remaining battery can carry only some portion of the load that could be handled by the original, non-failed complement of batteries.

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EXHIBIT 10 - BLACK BOX FAILURES

BLACK BOX TYPE	Number of Failures: Redundancy Provided And Operable	Redundancy Provided But Not Operable	No Redundancy Provided	TOTAL
Array Slip Ring Assemblies			1	1
Attitude Control Electronics	1			1
Batteries (only total number shown)				11
Command/Clock Power Supplies	1			1
Computers (on-board)	1		1	2
Gyros/IMU's	7			7
IMU Power Supplies	1	1		2
Memories	2			2
Panoramic Attitude Sensors	1			1
Radiometers	1	1	5	7
Radiometer Encoders	3	3		6
Reaction Wheel Power Supplies			3	3
Receivers, Wideband	2			2
Receivers, UHF	1			1
Tape Recorders	9	3	1	13
Telemetry Encoders	3			3
Transmitters, Wideband	1	1		2
TOTAL	34	9	11	65

In the update sample, there were 34 black box failures (not including batteries) where redundancy was available and operable. The major impact of these failures is therefore loss of redundancy protection. On twelve spacecraft, however, black box failures resulted in severe mission impacts. These are as follows:

- Termination of the SAGE mission due to battery failure
- Termination of the Viking Lander 2 mission due to computer failure
- Loss of the SEASAT mission due to failure in the array slip ring assembly
- Loss of the SMM mission due to consecutive failures in all three reaction wheel power supplies
- Loss of the TIROS-N mission due to failures in both redundant IMU power supplies.
- Loss of primary payload data on SMS-1 due to failure of both S-band transmitters
- Loss of primary payload data due to failure of both VISSR encoders on SMS-2, GOES-2, and GOES-3
- Restriction of primary payload data gathering to real-time only due to failure of both primary and redundant tape recorders on LANDSAT 2, NIMBUS-5, and NIMBUS-6.

The impacts of the remainder of the black box failures tabulated in Exhibit 10 fall somewhere between the severe ones and loss of redundancy protection. Ten of these remaining black box failures involve loss of a battery; the other 6 loss of a radiometer.

5. RFI/EMI

As indicated above, RFI/EMI ranks as an especially prevalent and persistent problem area. Of the 43 operating satellites in the update sample, 22 had RFI/EMI anomalies. The lack of such anomalies on the other 21 spacecraft may reflect lack of reporting rather than lack of such incidents. Overall, sixty-three anomalies caused by RFI/EMI were identified in the update sample, and they are distributed among various hardware areas as follows:

Scientific Instruments	11
Radiometers	8
Cabling/harness (cross-talk, coupling, etc.	8
Telemetry Transitters	3
Telemetry Monitors	3
UHF Receivers	2
Command Receivers	2
Battery Chargers	2
Attitude Sensors	2
Attitude Control Electronics	2
Spacecraft Clock	1
Command Decoder	1
Memory	1
Power Control Electronics	1
Thermal Control Electronics	1
S-band Transponders	1
Unknown	14

The anomalies represented above include cases of "internal" RFI where the extent and effects of the RFI were limited to the "black box" that generated it, and "external" RFI where the RFI generated in one area affected equipment in another area.

In making the above allocation of anomalies to equipment areas, the anomaly was charged to the offending equipment wherever there were sufficient data to make this assignment. This was clear-cut in cases of internal RFI. For external RFI, the equipment that was susceptible to RFI was charged with the anomaly if it appeared that the equipment would not have been susceptible had more adequate RFI protection been provided. The equipment generating the RFI was charged when it appeared that the magnitude of the RFI was sufficiently high to penetrate normally adequate RFI protection in other equipment. The "Unknown" category includes anomalies where this distinction could not be made. Making these assignments required assumptions when the data did not specifically identify the offending equipment. These assumptions were based on engineering judgment using the descriptions of the anomalies.

Many of the RFI/EMI anomalies did not significantly affect spacecraft performance. Some, however, were serious. In several instances, RFI/EMI caused significant losses of payload data. Also, in at least two instances the offending equipment had to be turned off and the back-up units selected, which resulted in loss of redundancy. Thus, it appears that in design and testing, the generation of, and susceptibility to, RFI/EMI warrants special consideration.

6. Deployments

On the spacecraft launches covered in this study sample, but not including spacecraft already covered in previous studies and updated in this sample, there were at least 71 deployment events. These events ranged from solar paddle and boom deployments to extensions of long antennas, but do not include separation or deployments involving simply the "spring-out" of short stub antennas and the like.

For these 71 deployment events, eight anomalies were reported. Of these eight, only one involved a deployment failure, namely, the deployment failure of the 10 meter, Z axis Vector Electric Field Instrument boom on DE-2. This anomaly was attributed to an open in the power circuit.

The remaining 7 deployment anomalies are summarized as follows:

- o The SAGE S-band antenna required 40 minutes to deploy; attributed to low temperature stiffness of a coaxial cable;
- o The LANDSAT-3 left solar paddle did not slew as expected at deployment, possibly due to shadowing of a sun sensor;
- o LANDSAT-4 was initially unsuccessful in deploying the K_u-band antenna;
- o On MAGSAT, only 1 of the 2 despin timers functioned; timer #2 never became armed, possibly due to higher than expected thermal resistance between the fourth stage and the timer;
- o On NIMBUS-7, several squibs on instruments did not fire until the firing commands were repeated;
- o On NOAA-7, an instrument earth shield door was slow to deploy, possibly due to a mechanical hang-up;
- o The Voyager 2 Science Boom deployed to within 0.06° of the correct position and did not latch; the two most likely causes reported are debris in the folding strut hinge or insufficient drive in the folding strut;
- o On Voyager 2, telemetry indicated that the RTG Boom Release pyro-amplifiers "A" activated; but not the "B" set of amplifiers; there was some evidence that a transistor in the output switching portion of the pyro switching unit failed.

7. Miscellaneous

This subsection discusses four additional observations of interest.

(1) Self Healing: The apparent self-healing capability which has been noted in previous data bank studies was again observed. In the update sample, there were 14 instances of anomalous behavior that cleared up without any type of intervention. These instances do not include "glitches" that occur once or a few times and then go away.

(2) Array Temperature Sensors: During the course of this study, it appeared that a large number of array temperature sensor failures were reported. Further analysis revealed that six such sensors had failed catastrophically, and that these failures had occurred on HCCM, ATS-6, GOES-1, GOES-3, IUE, and SMS-2.

(3) Plume Impingement: On previous data bank studies, anomalies were occasionally noted involving impingement of the propulsion plume on some spacecraft surface. Four such instances were noted during this study; one each on GOES-4, GOES-5, Voyager 1, and Voyager 2. On the Voyagers, this caused 20% less ΔV than was expected, and subsequently more hydrazine use. It was reported that post-launch analyses based on more sophisticated techniques than had been applied earlier produced results agreeing with the observed phenomena.

(4) Problems Corrected/Mitigated from the Ground: On all previous data bank studies, instances were frequently noted where the anomaly was corrected or mitigated by some action taken on the ground. During this update, 75 such instances were identified. These instances include only those where the anomaly was actually corrected or the anomalous hardware restored to acceptable status from the ground. They do not include commanding-in a redundant unit, commanding the spacecraft back to the proper configuration following spurious turn-ons/turn-offs by "glitches," nor establishing procedures to allow some unit to warm-up before use. Even with such exceptions, the number of anomalies corrected or mitigated from the ground in this sample is significantly larger than the numbers noted in the past. There appear to be several reasons for this, one of them being the more extensive use of on-board computers.

This more extensive use of on-board computers presents more opportunities for correcting anomalous behavior via on-board software modifications that change operating points or procedures. It also increases the likelihood of anomalous behavior due to software errors. Of the 75 cases where anomalies were corrected or mitigated from the ground, roughly 20% involved corrections to on-board software discrepancies.

V. PERFORMANCE EVALUATION

Typically, spacecraft performance begins at (or near) its design capability immediately after a successful launch and then degrades over time as it incurs a wide variety of anomalies. A procedure to quantify spacecraft performance, or capability, over time using the PRC space data base was derived in Reference 11.

Each spacecraft anomaly in the data base is assigned to one of five mission effect categories as described in Section III. The procedure to quantify spacecraft capability begins by assigning a single numeric to represent "average" spacecraft degradation in each category as shown below:

Mission Effect	Degradation
1. Negligible	0.025
2. Non-Negligible but Small	0.20
3. 1/3 to 2/3 Mission Lost	0.50
4. 2/3 to Nearly Total Mission Lost	0.80
5. Essentially Total Mission Lost	0.975

Thus, spacecraft capability starts at 1.0 and remains there until occurrence of of the first anomaly, when it is assumed to degrade by exactly the percentage assigned to its mission effect category. If this value is designated D_1, then at this point in time spacecraft capability is given by $(1 - D_1)$. Spacecraft capability is assumed to remain at this value until occurrence of the second anomaly with degradation D_2. Spacecraft capability is then assumed to be given by the product $(1 - D_1)$ $(1 - D_2)$. In general, spacecraft capability is

$$C = \prod_{i=1}^{n} (1 - D_i)$$

upon the occurrence of the nth anomaly and remains at this level until the occurrence of anomaly n + 1. Plotting these results provides a highly visual indication of the degradation in spacecraft capability over time. Integrating the resultant curve over the spacecraft's operating (or design) life and normalizing provides a single numeric representing average capability.

The procedure, while being easy to apply and useful in some applications, may not always provide an accurate portrayal of spacecraft performance. It is the purpose of this subsection to examine four specific reasons why this might be so and to suggest an improved procedure suitable for general application.

(1) The criticality categories permit the possibility of large accumulated errors in the capability estimate particularly for accumulations of trivial anomalies.

This criticism is particularly apropos for complex, well-documented spacecraft. A case in point is NIMBUS-7, reported herein. It has accumulated 53 category 1 anomalies and 8 category 2 anomalies for a current estimated capability, using the current procedure, of

$$C = (0.975)^{53} \quad (0.8)^{8} = 0.044.$$

The spacecraft in fact is operating quite well in spite of its 61 anomalies, much better than the capability figures of 4.4 percent would imply. The solution to this problem lies in making a more accurate assessment of the mission impact of each anomaly and carefully tracking the cumulative impact of all anomalies. The latter is a good deal easier than the former. That is, determining the impact of each of the first ten NIMBUS-7 anomalies is probably at least ten times as difficult as determining the state of NIMBUS-7 after the tenth anomaly. Careful application of these two approaches, however should adequately overcome this drawback.

(2) Assignment of anomalies to the categories is highly judgmental with no formal rules for making these assignments.

The informal rule for assigning anomalies to categories is to establish the overall effect on the mission as if the anomaly had occurred in isolation and at the beginning of the mission. Anomalies in redundant units take into account the degree of redundancy available upon their occurrence. Otherwise this approach does not include cumulative or cancelling effects of anomalies. While the assignments are judgmental, it is fairly easy to make the right assignment because the five categories are fairly broad and are tailored to the actual results observed in practice. Furthermore, there is no totally objective way to determine the impact of most anomalies. TV pictures or communications links that are degraded or fuzzy or intermittent, etc., are common anomalies for which this is true. Furthermore, the apparent objectivity inherent in "40 frames of data lost" or "2 transponders failed," etc., may be more illusory than real, requiring agreement that all frames/transponders are equal and so on. The impact of anomalies on scientific missions is generally even more subjective.

One approach to this problem might be to have an expert (or experts) assign the anomalies to their mission effect categories and justify each assignment, in writing, on the basis of all available information. It might also be possible for the expert(s) to prepare ground rules for anomaly classification and then to review the results for realism.

(3) The method for combining the effects of anomalies (i.e., as products), while mathematically advantageous, appears deficient in describing the performance.

The best way to determine how deficient this method is, is to compare its application with the actual curve. But if one had the actual curve there would be no need to apply the method at all. Thus, deriving an actual curve, or at least one approaching as closely as possible to the actual, would obviate this problem.

(4) No distinction is made between engineering performance and science performance.

Assume that each spacecraft can be rather neatly divided into two parts. One is the basic bus; the structure, power supply, attitude control, communications, thermal control, etc.; and the other is the payload, e.g., multi-spectral sensor, TV cameras, magnetometers, etc. Given this division, it would be of interest to know how well the bus was performing (engineering performance) and how well the payload was performing (science performance). It is entirely possible, of course, that under particular scenarios of redundancy, load sharing, and work-arounds that both bus and payload could be doing rather poorly while the mission itself was being accomplished quite satisfactorily. Thus, the distinction between engineering and science performance might best be drawn by making three evaluations upon the occurrence of each anomaly, i.e., its mission effect, its payload effect, and its effect on the bus.

An Improved Procedure

Combining these responses into an overall procedure would not only avoid the four drawbacks discussed above, but would also provide a generally superior way to assess spacecraft capability as a function of time. Specifically, the new procedure might consist of the following steps. (1) Assign "experts" to implement the procedure for each spacecraft or to review the results of more general practitioners. (2) Have the experts and/or practitioners gain familiarity with the total spacecraft design, mission, results, and anomalies. (3) Assign to each anomaly three cumulative degradation factors to the nearest percentage point, one for the mission, one for the payload, and one for the bus.* Since some anomalies have a degradation effect over time it will probably be useful in most cases to also assign cumulative degradation factors at some convenient time intervals such as every 1000 hours or every quarter. These assignments would be an evaluation by experts or practitioners of the cumulative capability lost at a given point in time for the total spacecraft, the bus, and the payload. (4) Provide a written justification for each assignment. (5) Plot the resultant curves and normalize as before.

---

*Note that it may also be necessary to introduce a factor to account for self-healing and hence improvements in capability.

We, as practitioners, attempted to apply the procedures to SAGE (AEM-2), a fairly simple spacecraft with a fairly straightforward mission profile. The results were not encouraging. Estimating the actual impact of each anomaly has proven to be time consuming, difficult, and ultimately arbitrary in large part. This may be due simply to our lack of in-depth familiarity with the system and its mission. Real experts operating more nearly in real time might ease the process considerably and provide more accurate results.

Our attempt to implement the procedure is documented in Exhibit 11. The results for the mission are plotted in Exhibit 12 together with the results of applying the current methodology. It is assumed in both exhibits that the mission degradation is linear, going from 50 percent after the battery anomaly (2050 hours) to zero at the end of the mission (25,270 hours).

The proposed method gives an average capability over the spacecraft's operating life of 54 percent; the current method yields 18 percent. The design life for SAGE is 12 months. Average capability over this period is 76% using the suggested method and 28% using the current method. The differences are clearly significant. How general this phenomenon is with respect to other spacecraft is unknown.

The improved procedure is obviously a good deal more time consuming than the current one. The difference is almost totally in the derivation of the three cumulative degradation factors together with the written justifications required by the improved procedure. In the current procedure this is a simple exercise in multiplication. While it will take some experience in the application of the improved method to

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EXHIBIT 11 - SAGE PERFORMANCE EVALUATION

Anomaly Index	Time of Occurrence (Hours)	Estimate of Cumulative Degradation (%) Payload	Bus	Mission	Remarks
1	ε	0	0	0	A longer than nominal time to deploy the S-band antenna does not degrade bus, payload, or mission.
2	ε	0	2	0	Hotter than normal base module temperature had no immediate payload or mission effect but contributed to the shortened battery life.
3	455	0	4	0	The higher than predicted scan wheel temperature had no payload or mission effect. Bus drifting further from nominal.
4	500	0	5	0	Loss of one memory location has no payload or mission effect but does further degrade the bus a bit.
5	1,295	0	6	0	Initial frequency shifts in the S-band transmitter can be worked around to avoid mission degradation. The bus is again a bit further from nominal.
6	2,050	0	56	50	The degraded battery capacity precluded many spacecraft operations. Continuing decline in battery capacity leads to complete failure at 25,270 hours.
7	2,750	5	57	52	The failure of the sun edge detector circuit had no mission effect because a suitable work-around was developed. It did not degrade the bus but the payload is degraded on the order of 5 percent. Additional degradation shown in bus and mission capability is due to the earlier battery anomaly.
8	5,[illegible]80	5	61	57	The degraded voltage limiter actually improved the bus a percentage point or so by preventing the dumping of excess shunt current into the battery. Continuing battery degradation of about 5 percent results in cumulative bus degradation of 4 percent. This anomaly had no payload effect and no added mission effect. The continuing decline in battery capacity caused a further decline of 5 percent in mission capability, however.
9	7,100	5	65	61	Higher than normal attitude errors for four passes result in no further degradation of payload, bus or mission. The continuing battery decline is reflected in the bus and mission degradation factors.
10	8,850	5	70	65	Abnormal variations in the horizon scan wheel are another outgrowth of the battery problem. The bus is judged to be slightly more impacted than the mission.
End of Life	25,270	5	100	100	Mission termination is the end result of the battery anomaly (#6).

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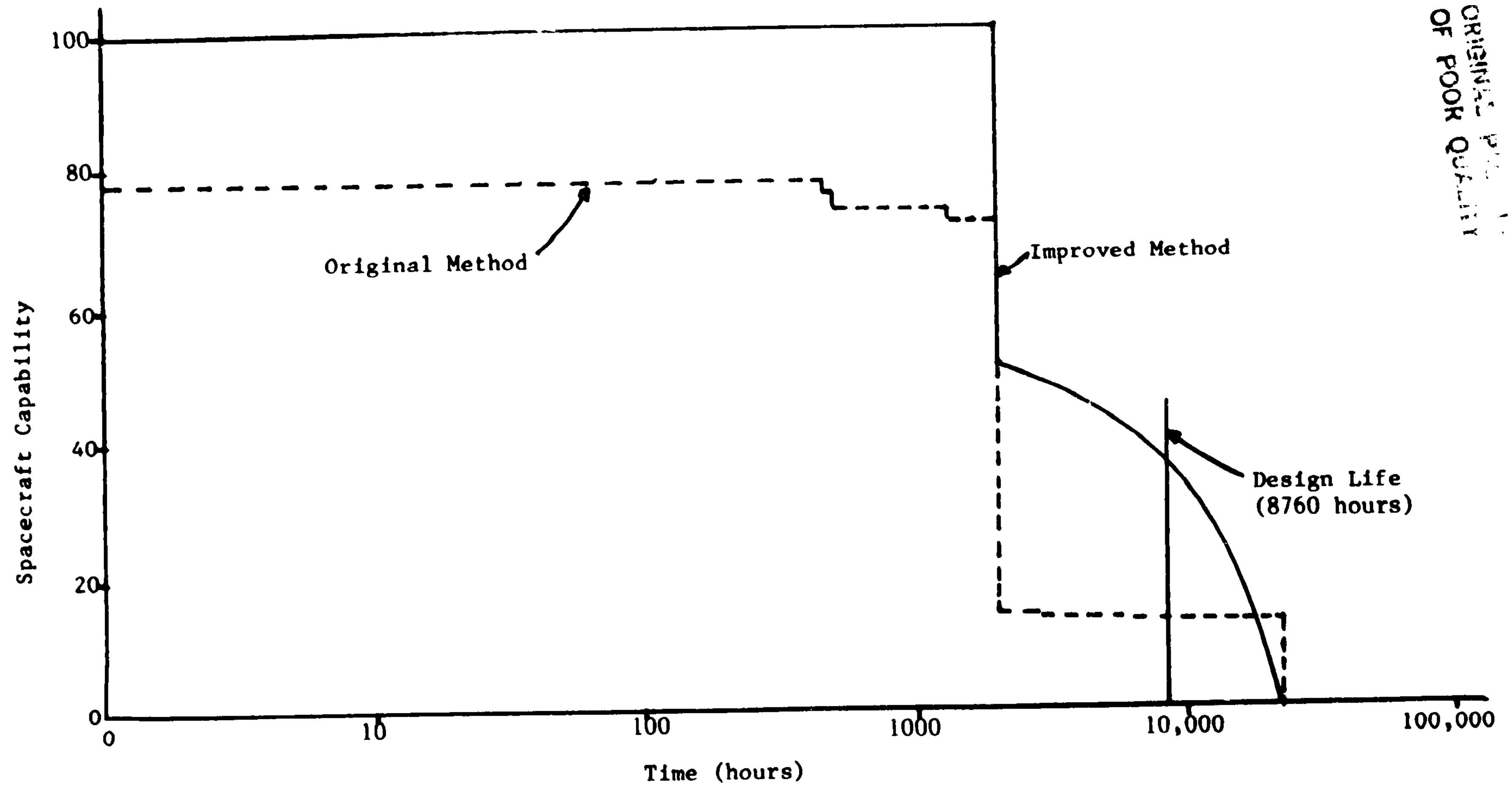

EXHIBIT 12 - SAGE CAPABILITY PLOTS

determine how long it would take, a rough estimate that seems reasonable to the authors is 15-30 minutes per anomaly, if the procedure is implemented at the time the EARs are generated or by someone who is already intimately familiar with the spacecraft, its mission, and its anomalies.

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APPENDIX A

DATA BANK COVERAGE FOR THIS UPDATE

APPENDIX A

DATA BANK COVERAGE FOR THIS UPDATE

The chart in this appendix lists the spacecraft for which information was added to the data bank by this study.

For each spacecraft, the chart shows the number of the engineering analyses report (EAR) that backs up the data in this report and gives an indication of the degree of completeness of the four major tables in the EAR. Information for Table III (parts counts by major components) was not actively sought in this study and that for Tables V and VI (developmental and prelaunch activities) varied from essentially none to fairly comprehsive. Information on developmental activites, however, was not generally available from those sources that provided the spacecraft operational data and a separate collection effort was not undertaken to seek information of this kind.

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DATA BANK COVERAGE

EAR NO.	SPACECRAFT	TABLE I GENERAL INFORMATION	TABLE II OPERATING TIME/SYSTEM BREAKDOWN	TABLE III PARTS BREAKDOWN	TABLE IV FAILURE DESCRIPTION
65	AE-5	Complete	Complete	Nil	Complete
66	AEM-A (HCCM)	Complete	Complete	Nil	Complete
	AEM-B (SAGE)	Complete	Complete	Nil	Complete
67	ATS-1	Complete	Complete in EAR 40; 1982 update in this EAR	Complete in EAR 40	Sketchy
	ATS-3	Complete	Complete in EAR 40; 1982 update in this EAR	Complete in EAR 40	Sketchy
	ATS-5	Complete	Complete in EAR 40; 1982 update in this EAR	Complete in EAR 40	Complete
	ATS-6	Complete	Complete in EAR 48; 1982 update in this EAR	Nil	Complete
68	DE-1	Complete	Complete	Nil	Complete
	DE-2	Complete	Complete	Nil	Complete
69	GOES-1	Complete	Complete in EAR 60; 1982 update in this EAR	Nil	Complete
	GOES-2	Complete	Complete in EAR 60; 1982 update in this EAR	Nil	Complete
	GOES-3	Complete	Complete	Nil	Complete
	GOES-4	Complete	Complete	Nil	Complete
	GOES-5	Complete	Complete	Nil	Complete
70	IMP-8	Complete	Complete in EAR 56; Sketchy data 1982 update	Partial parts data in EAR 56	Complete in EAR 56; little detail 1982 update
71	ISEE-1	Complete	Complete	Nil	Complete
	ISEE-2	Complete	Complete but Sketchy	Nil	Sketchy
	ISEE-3	Complete	Complete	Nil	Complete
72	IUE	Complete	Complete	Nil	Complete
73	LANDSAT-2	Complete	Complete in EAR 54; 1982 update in this EAR	Complete in EAR 54	Complete
	LANDSAT-3	Complete	Complete	Nil	Complete
	LANDSAT-4	Complete	Sketchy	Nil	Sketchy
74	MAGSAT	Complete	Complete	Nil	Complete
75	NIMBUS-4	Complete	Complete in EAR 8; No data 1982 update	Complete in EAR 8	Sketchy data for 1982 update
	NIMBUS-5	Complete	Complete in EAR 62	Complete in EAR 62	Complete
	NIMBUS-6	Complete	Complete in EAR 62	Complete in EAR 62	Complete
	NIMBUS-7	Complete	Complete	Same as NIMBUS-6	Complete
76	NOAA-4	Complete	Complete in EAR 61; 1982 update in this EAR	Nil	Complete
	NOAA-5	Complete	Complete in EAR 61; 1982 update in this EAR	Nil	Complete
	NOAA-6	Complete	Complete	Nil	Complete
	NOAA-B	Complete	Not Applicable	Not Applicable	Not Applicable
	NOAA-7	Complete	Complete	Nil	Complete
79	SMM	Complete	Complete	Nil	Complete
80	SMS-1	Complete	Complete in EAR 60; 1982 update in this EAR	Nil	Complete
	SMS-2	Complete	Complete in EAR 60; 1982 update in this EAR	Nil	Complete
81	TIROS-N	Complete	Complete	Nil	Complete
82	SEASAT	Complete	Complete	Nil	Complete
83	SME	Complete	Complete	Nil	Complete
84	VIKING ORBITER-1	Complete	Complete in EAR 47; 1982 update in this EAR	Complete in EAR 47	Complete in EAR 47; 1982 update in this EAR
	VIKING LANDER-1	Complete	Complete in EAR 47; 1982 update in this EAR	Complete in EAR 47	Complete in EAR 47; 1982 update in this EAR
	VIKING ORBITER-2	Complete	Complete in EAR 47; 1982 update in this EAR	Complete in EAR 47	Complete in EAR 47; 1982 update in this EAR
	VIKING LANDER-2	Complete	Complete in EAR 47; 1982 update in this EAR	Complete in EAR 47	Complete in EAR 47; 1982 update in this EAR
85	VOYAGER-1	Complete	Complete	Nil	Complete
	VOYAGER-2	Complete	Complete	Nil	Complete

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APPENDIX B

BASIC DATA TABULATIONS

APPENDIX B

BASIC DATA TABULATIONS

This appendix is divided into three tabulations. Appendix B-1 summarizes each anomaly in the update. Appendix B-2 contains classification codes for each anomaly using the "standard" approach applied to all previous collections. Appendix B-3 contains additional classification codes applied in this study. Sections III.A and III.B in the main body of this report define the various codes and discuss their application to the spacecraft anomalies. For convenience, the identification of the anomaly characteristics and the alpha-numeric codes employed are repeated just prior to the two tabulations of Appendices B-2 and B-3.

Appendix B-1 contains, in tabular form, the primary data upon which this report is based. All 606 satellite anomalies are listed by spacecraft, in order of elapsed time to occurrence and contain these data elements:

- Time-to-occurrence of anomaly in hours. A time t is associated with the launch interval, prior to injection into orbit. The symbol denotes either unknown time or intermittent occurrence.
- Three short phrases indicating the description of the observed anomaly, its suspected or known cause, and the effect on the mission objective(s).
- Corrective actions, both in-orbit or for subsequent launches, if known.
- Brief remarks, if needed to place the anomalous incident in context.

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The sequential coding index of column 1 provides a means of cross-referencing to the classification codes of Appendix B-2 and B-3. These two appendices should facilitate any further classification or analysis the reader might wish to undertake.

Appendix B-1 begins on Page 83, Appendix B-2 on Page 155, and B-3 on page 175. A list of acronyms used in the anomaly summaries and their definition follows for the convenience of the reader.

ACS	Attitude Control System
AGC	Attitude Gain Control
APU	Auxiliary Processing Unit
AVHRR	Advanced Very High Resolution Radiometer
BCS	Bent Crystal Spectrometer
BOT	Beginning of Tape
C&DH	Command and Data Handling
CDA	Command and Data Acquisition
CDIU	Command and Data Interface Unit
CIU	Controls Interface Unit
COMSTOR	Command Storage Module
C/P	Coronagraph/Spectrometer
CPU	Central Processing Unit
CTU	Central Telemetry Unit
CZCS	Coastal Zone Color Scanner
DAPU	Data Acquisition and Processing Unit
DCPR	Data Collection Platform Receiver
DCS	Data Collection System
DDP	Digital Data Processor
DIP	Digital Information Processor
DSAS	Digital Solar Aspect Sensor
DTR	Digital Tape Recorder
ECAM	ERTS Command Auxiliary Memory
ERB	Earth Radiation Budget
ESA	Earch Sensor Assembly
ESMR	Electrically Scanning Microwave Radiometer
FCS	Flat Crystal Spectrometer
GCMS	Gas Chromatograph Mass Spectrometer
GEODAT	Software
HAO	High Altitude Observatory
HDRSS	High Data Rate Storage System
HEPAD	High Energy Particle Detector
HET	High Energy Telescope
HIRS	High Resolution Infrared Sounder
HRIR	High Resolution Infrared Radiometer
IDC	Image Dissector Camera
IMU	Inertial Measurement Unit
LAPI	Low Altitude Plasma Experiment
LIMS	Limb Infrared Monitoring of the Stratosphere
LSAD	Left Solar Array Drive
LVDT	Linear Voltage Differential Transformer
MSS	Multispectral Scanner
MSU	Microwave Scanner Unit

NBTR	Narrow Band Tape Recorder
NEMS	Nimbus-E Microwave Spectrometer
OAS	Orbit Adjust System
OBC	On-Board Computer
PAS	Panoramic Altitude Sensor
PCL	Program Control Logic
PCM	Power Control Module
PCS	Pointing Control System
PMT	Photomultiplier Tube
RBV	Return Beam Vidicon
RCS	Reaction Control System
RIU	Remote Interface Units
RMP	Rate Measuring Package
RTG	Radioisotope Thermoelectric Generator
RVDT	Rotary Variable Differential Transformer
SAD	Solar Array Drive
SAM II	Stratospheric Aerosol Measurement II
SAMS	Stratospheric and Mesopheric Sounder
SAR	Synthetic Aperture Radar
SASS	Scatterometer
SBUV	Solar Backscatter Ultraviolet Energy
SEM	Space Environment Monitor
SIRS	Satellite Infrared Spectrometer
SMART	Housekeeping Software
SMMR	Scanning Multichannel Microwave Radiometer
SNR	Signal to Noise Ratio
SR	Scanning Radiometer
SRR	Scanning Radiometer Recorder
SSCA	Surface Sampler Control Assembly
SSU	Stratospheric Sounding Unit
TCE	Thermal Control Electronics
TED	Total Energy Detector
THIR	Temperature/Humidity Infrared Radiometer
TIP	Tiros Information Processor
TOMS	Total Ozone Mapping Spectrometer
TWERLE	Tropical Winds Energy Conversion Reference Level Experiment
TWTA	TWT Amplifier
VAS	Visable Infrared Spin Scan Radiometer Atmospheric Sounder
VEFI	Vector Electric Field Instrument
VHRR	Very High Resolution Radiometer
VIP	Versatile Information Processor
VIRR	Visable and Infrared Radiometer
VISSR	Visable Infrared Spin Scan Radiometer
VTPR	Vertical Temperature Profile Radiometer
WBVTR	Wide Band Video Tape Recorder
WEFAX	A Satellite Weather Facsimile System

APPENDIX B-1

ANOMALY SUMMARIES

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		AE-5				
1	*	Memory contents changed after loading and verification. Garbling occurs in both memory units after operation of all four torquer coils.	Suspect proximity of torquer coils to programmer-to-memory harness garbles memory address. Exact mechanism unknown.	Minimal effect due to corrective action.	Loaded zeros in memory locations subject to garbling and restricted use of torquer coils to two at any one time.	
2	*	Thruster control harness connections in error.	Quality control.	Minimal effect.	Changed command routines to obtain compatibility with thrusters.	
3	*	Shunt limiter #1 occasionally trips for no apparent reason.	Unknown.	Minimal effect.	When the shunt limiter trips, it is commanded back on.	
4	285	Ion repeller current in neutral atmosphere composition experiment increased slightly and data output counts decreased.	Attributed to temporary short in ion extraction lens.	Minimal effect		Problem cleared itself and experiment operated normally after about 3½ days.
5	13,745	Backscatter ultraviolet spectrometer ceased operation.	Cause unknown.	Some loss of data from one of 12 experiments.		After about 20,000 hours the experiment returned to normal.
6	41,760	Noisy wheel horizon sensor data occurred intermittently.	Cause unknown.	Effect minimal although it caused the pitch loop to lose lock and allow the spacecraft body to rotate.		Problem went away by itself after about a week.
7		Numerous under voltage shutdowns of the spacecraft occurring intermittently.	Design problem.	Loss of 4-5 minutes of data out of a 96 minute sequence when the problem occurs.		Problem resulted from an attempted to prolong battery life on AE-5 relative to AE-3 and 4.

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		AEM-2 (HCMM)				
1	*	The heat capacity mission radiometer patch temperature controller controls at 117 K instead of 115 K.	Unknown, but it could be a shift in the set point on the telemetry.	No mission effect.		
2	*	The clock frame count and word count were not synchronized.	Design problem.	Minimal impact since spacecraft operates in real time.	Design modified for next spacecraft in the series (SAGE).	
3	*	Cross-talk in harness.	Design problem.	No effect. Possibility of spurious commands but operational work-around developed to preclude them.	Design modified for next spacecraft in the series (SAGE).	
4	*	Telemetry frame counter, frame-, length hold register, takes on an arbitrary state when powered.	Design problem.	No effect.	Operational work-around	
5	*	Stop/shifts in frequency of S-band transmitter.	Design problem.	Slight impact; oscillator needs to be warmed up before achieving stable status.		
6	*	Sun sensor reticle loses low sun angles, i.e., loses most significant bits.	Possibly due to poor workmanship.	No effect on spacecraft operation. Slight impact on data reduction, causing brief periods of loss of yaw determination accuracy		
7	330	The platinum sensor (telemetry point) on the array-x paddle opens at 0 °C, or below.	Quality problem. Not a flight worthy device.	No mission effect.		
8	500	The spacecraft went into acquisition mode and the battery over temperature circuit [illegible]	Spurious commands possibly due to cross talk in the harness.	Minimal effect; did not recur.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		AEM-1 (HCCM)				
9	6,210	Battery temperature increased necessitating reduced charge levels.	Cadmium migration in the battery cells.	Significant reduction in science data collection.	Problem persisted in spite of operational work-arounds, i.e., cycling loads and the battery, etc.	Similar batteries on SAGE launched subsequent to this anomaly.
10	8,110	The momentum compensation motor of the heat capacity mapping radiometer temporarily stalled, later stopped permanently.	Possibly due to foreign matter in the lubricant.	Small effect since ground work-around developed to compensate for yaw axis errors.		
11	14,985	Long clock stops.	Spacecraft power problems.	Loss of S-band and instrument operation.	Attempted work-arounds to no avail.	
12	-	Clock reject counter advances between some passes.	Attributed to RFI in some geographical regions.	No mission effect.		
13	-	The heat capacity mapping radiometer cooler housing and cone run 10°C cool with door closed and heater on.	Unknown.	No mission effect.		
		AEM-2 (SAGE)				
1	-	S-band antenna required 40 minutes to completely deploy.	Coaxial cable slowed deployment due to low temperature stiffness.	No effect.		
2	-	Base module temperature runs hotter than than predicted.	Attributed to design (thermal analysis) but specific error unknown.	Contributed to shortened battery life, etc.		
3	455	Scan wheel temperature rose well above predicted.	Design error in modeling absorbed sunlight on panels.	No mission effect.		
4	[illegible]	Command stored in memory location not executed when clock cycles to [illegible]	Logic design error.	No effect; memory location not used.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		AEM-2 (SAGE)				
5	1,295	S-band transmitter frequency shifts after turn on.	Design problem; crystal oscillator requires warm-up.	No mission effect transmitter commanded on to stabilize before data transmission.		
6	2,050	Battery capacity degraded; spacecraft went into under voltage condition.	Attributed to cadmium migration; exacerbated by thermal control problem.	Significant impact. Operating voltage reduced from 30 to 20 volts. Led to command and attitude control problems and increasing loss of experiment data.		
7	2,750	Instrument scan head went into stops instead of reversing scan at sun edge (did not sense sun edge).	Due to failure of sun edge detector circuit.	No mission effect.	Work-around developed using science detector.	
8	5,180	Voltage limiter degraded.	Unknown cause.	No added mission effect.		Fortuitous because degradation matched the degraded power levels caused by the battery anomaly (It prevented dumping excess shunt current into the battery).
9	7,100	Four passes with higher than normal attitude errors and wheel activity.	Low voltage spikes on the ACS power supply for unknown reason.	No mission effect; did not recur.		
10	8,850	Horizon sensor scan wheel had abnormal speed variations.	Combination of spacecraft power problems and sun interferences.	No significant effect.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ATS-1				
1	-	Propellant was lost during the first eclipse.	Unknown.	Insignificant; spacecraft has been operating off vapor pressure.		
2	12,[illegible]	A number of false commands were executed.	Unknown.	Insignificant.		
3	12,[illegible]	Continued drop in impulse per pulse of stationkeeping system 2.	Unknown.	Insignificant, stationkeeping still possible.		
4	-	Some battery degradation.	Unknown.	Significant, not enough power to support C-band operations.		
5	-	Some array degradation.	Unknown.	Significant; not enough power to support C-band operations.		
		ATS-3				
1	-	Some portions of C-band have failed.	Unknown.	Small effect.		
2	-	Control gas has been depleted.	Unknown.	Small effect.		
3	-	Some array degradation.	Unknown.	Signi[illegible]ant; not enough power to support C-band operations.		
4	-	Some battery degradation.	Unknown.	Significant; not enough power to support C-band operations.		
		ATS-5				
1	1,850	RF leakage through the C-band antenna select switch causes RF power loss.	Due to design.	Significant; C-band power loss.		End of life tests indicated that the switch might be erratic.
2	26,300	Array slightly damaged	Caused by large solar flare	Small, array degradation.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ATS-5				
3	39,140	L-band TWT #3 failed.	Unknown.	Negligible.		
4	96,380	Television camera system sun shutter not operative.	Due to spin of the spacecraft.	No impact; television not used as planned because the spacecraft was spinning.		The shutter was not designed for a spinner and its shutter actuator could not overcome the force of the spin.
5	99,450	Undervoltage condition on Battery #1 during end of life tests.	Possibly caused by partial failure of the battery.	No effect.		
6	99,700	Telemetry readings from power bus #2 fluctuated during end of life tests.	Caused by solar array damage from apogee engine eject.	No effect.		
7	99,700	End of life tests indicated that A to D converter components may have changed values.	Possibly due to aging.	No effect.		
8	99,700	End of life tests indicated that array degradation was 18% greater than predicted.	Unknown.	No effect.		
9	-	Insufficient battery capacity to carry C-band operations through eclipse.	Probably due to aging.	Small.		
		ATS-6				
1	17,730	North solar array lost 20 watts capability.	Unknown.	Negligible.		
2	23,470	Failure of SPS-2 negative yaw jet #13.	Due to propellant feed blockage.	Negligible.		Anomaly first in a series of propulsion/thruster problems; initially negligible impacts but later, backup and work-around approaches less possible.

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ATS-6				
3	23,880	Failure of SPS-2 negative roll jet #9.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
4	23,880	Low initial impulse pulses on positive pitch jet #12 (SPS-2).	Due to propellant feed blockage.	Negligible.		See anomaly #2.
5	24,816	SPS-2 negative roll jet #9 leaked for about a day.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
6	25,920	Complete failure of Environmental Measurements Experiment, Auroral Particles.	Unknown.	Loss of a portion of the EME measurements.		
7	27,384	Less than nominal firing performance of SPS-2 positive pitch jet #2 and later degraded further.	Due to propellant feed blockage.	Negligible.		
8	27,390	Unexpected variances in spacecraft IF AGC calibrations.	Unknown.	Negligible.		
9	30,240	SPS-1 negative roll jet #1 stuck partially open for about five minutes after it was commanded to close.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
10	31,704	SPS-1 positive pitch jet #4 was found to be inoperative.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
11	32,040	Less than nominal performance from SPS-2 negative pitch jet #11; later returned to normal.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
12	32,184	Less than nominal performance from SPS-2 positive roll jet #10.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
13	34,176	SPS-1 negative yaw jet #6 was found to be completely inoperative.	Due to propellant feed blockage.	Negligible.		See anomaly #2.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ATS-6				
14	35,088	SPS-1 negative roll jet #1 remained firing for about seven times longer than normal.	Due to propellant feed blockage.	Negligible		See anomaly #2.
15	37,920	Degraded thrust level from SPS-2 eastward back-up orbit control jet #16.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
16	38,256	Degraded thrust level from SPS-2 eastward prime orbit control jet #15; later failed to fire.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
17	43,296	Intermittent telemetry data from DACU-2 analog channels with the number of effected channels progressing with time.	Most likely cause is an intermittent in the multi-layer printed circuit board.	Some loss of telemetry data.		
18	44,232	Many external thermistors had become erratic.	Attributed to long-term cycling in orbit.	Some loss of temperature telemetry data.		
19	44,856	SPS-1 negative roll jet #1 failed to fire.	Due to propellant feed blockage.	Negligible.		
20	44,856	SPS-1 positive yaw jet #5 failed to fire.	Due to propellant feed blockage.	Negligible.		See anomaly #2.
21	45,000	One frequency channel of the interferometer failed during end of life tests.	Unknown.	No impact on mission; mission was over at this point.		
22	45,000	During end of life tests, it was found that the Polaris tracker still interfered with the earth sensor.	Attributed to noise transients.	Not serious.		
23	45,000	Slight increase in reaction wheel friction and windage torque were noted during end of life [illegible]	Unknown.	Not serious.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
		ATS-6				
24	-	Diurnal variations in reflector temperature gradients produced reflector distortions.	Unknown.	Insignificant.		Caused "squinting" of the RF boresight off the spacecraft mechanical axes.
25	-	Heat pipe thermal diode exhibited some apparent non-condensible gas generation.	Unknown.	Insignificant.		Subsided after the first 2½ years in orbit.
26	-	Heat pipe gas reservoir ran hotter than nominal.	Due to degradation of the second surface mirrors (optical solar reflectors) that cover the reservoir's radiation.	Insignificant.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		Anomalies				
		DF-1				
1	ε	Horizon sensor erroneously turns off when transmitter turns off.	Due to coupling between two command lines.	No effect due to work-around.	The horizon scanner "on" command was placed into memory to be executed after transmitter turned off.	
2	ε	Telemetered data from sun sensor inverted (i.e., 1's and 0's interchanged).	The cause was a design error in that the documentation supplied by the manufacture contained incorrect telemetry format.	Negligible	Software was reprogrammed to invert and get the correct bit pattern.	
3	240	Transponder failed to turn off after uplink carrier dropped.	Suspected to be due to RFI.	No impact on mission.		
4	364	Sensor cover telemetry incorrect.	Unknown.	No effect; telemetry data indicated cover did not deploy; experimental data proved that it did.		
5	637	Plasma wave loop deployment telemetry incorrect.	Unknown.	No effect; telemetry data indicated loop did not deploy; experimental data proved that it did.		
6	644	Transponder down link carrier was on prior to scheduled ground station acquisition (it should have been off).	Unknown, but telemetry data indicate the receiver locked.	No effect; did not recur.		
7	880	The memory in the retarding ion mass spectrometer dumped prior to power off. After power off and on again, memory contents had been changed in two positions.	Unknown.	Negligible.	Work-around developed to reinitialize the memory at each power on.	
8	1,720	The command in memory location 543 executed 68 minutes early.	Attributed to bit value change in the stored command, but cause unknown.	No mission effect; did not recur.		

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		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		DE-1				
9	2,075	Loss of transponder subcarrier.	Unknown.	Negligible effect; subcarrier returned after some on/off commands transmitted. Problem did not recur.		
10	2,177	A command which is not used in the spacecraft was found in memory. No record exists of loading such a command.	Unknown.	No effect; command canceled.		
11	2,880	The high voltage power supply failed on the high altitude plasma indicator.	Probable cause is voltage break at one or more of several capacitors or an insulation breakdown.	Loss of perhaps 10 percent of mission data, and two-thirds of the high altitude plasma data.		The identical power supply also failed on the low altitude plasma indicator of the DE-2 spacecraft.
12	5,135	The lower of one of six active thermal control units opened fully rather than as required to maintain temperature.	Transistor failure in associated amplifier.	Little mission effect; temperatures controlled to within limits by operational work-arounds.		
13	6,890	Excessive lock drift.	Unknown.	Negligible due to periodic GMT adjustments.		Drift is 407 milliseconds per day. DE-2 clock also drifts excessively.
14	6,900+	Numerous glitches in spacecraft operation. E.g., unexplained 7 to 10 watt power increase on spacecraft bus; apparent loss of a microprocessor in the command and telemetry processor.	Radiation "hits" impinging spacecraft clock, etc.	Some lost and incorrect telemetry data.		"Hits" seem random geographically. Has happened on eight occasions.

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		DE-2				
1	ε	Z-antenna for the vector electric field instrument (VEFI) did not deploy.	Attributed to an open in the power circuit since no motor current shown on telemetry whereas other parameters were normal.	VEFI is one of 9 experiments on the spacecraft. It suffered significant loss since no direct measurements of east-west electric field were possible.		
2	ε	One of two battery chargers does not correctly control charge; protective circuitry disconnects the charges.	Caused by short in charge controller summing point to signal ground.	Until 840 hours science operation was cut back approximately 10 percent. At 840 hours the problem disappeared and did not recur.		
3	70	Malfunction in one segment of the Retarding Potential Analyzer Memory.	Unknown.	Negligible, work-around is straightforward.		
4	74	Telemetry downlink noisy when ranging enabled and no uplink ranging tones being sent.	Unknown.	Makes command verification difficult.	Work-around developed; either disable ranging or transmit uplink ranging tones.	
5	450	Fine sun sensor beta electronics changed gain and bias setting.	Unknown.	Negligible.	Conversion algorithm modified. When gain shifted again, horizon sensor data used more extensively for attitude determination.	
6	795	Nutation damper loop opens erratically and recurrently via automatic disconnect.	Noise spikes during on board computation of roll angle adversely influence the pitch control electronics.	Causes minor perturbations in attitude.	At each occurrence the damper loop is commanded closed again.	
7	1,430	Spacecraft body is offset by about 0.4° whenever the transponder turns on.	Due to noise coupling which causes the ACS to "think" it must correct an attitude error.	Not serious.	Work-around developed.	

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		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		DE-2				
8	3,400	Loss of telemetry enable pulse for encoding and transferring digital data.	Unknown.	Significant reduction in low altitude plasma instrument data. Lesser impact on vector electric field instrument. (Two of 9 experiments)		
9	5,300	High voltage power supply for the low altitude plasma instrument (LAPI) failed.	Unknown.	Loss of ½ the experiment's sensors. Not much additional degradation beyond that caused by anomaly 8. LAPI is one of 9 experiments.		Identical power supply also failed on the high altitude plasma instrument on the DE-1 spacecraft.
10	6,890	Excessive clock drift; approximately 130 milliseconds per day.	Unknown.	Negligible due to periodic GMT adjustments.		DE-1 clock also drifts excessively.
		GOES 1				
1	22,410	One side of the telemetry subsystem failed.	Unknown	No effect since redundant subsystem used.		
2	26,560	Visible/infrared spin scan radiometer hung up temporarily.	Unknown	Negligible effect.		Occurred once again two months later.
3	30,120	Infrared data from the visible/infrared spin scan radiometer lost intermittently for about a year from anomaly time, then lost completely.	Unknown	Loss of perhaps 20 percent of total spacecraft capability.		
4	56,976	Spacecraft cannot be commanded when VHF transmitter #1 is on.	Unknown	Command capability lost lost for three days.	Switched to VHF transmitter #2 and used S-band system as a backup.	

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-1				
5	-	One solar array temperature sensor failed.	Unknown.	Insignificant.		
		GOES-2				
1	8,760	Photomultiplier tube #1 failed in the visible/infrared spin scan radiometer (VISSR).	Unknown.	Degraded operation of the VISSR.		
2	13,200	Encoder in the VISSR failed.	Unknown.	No effect due to redundancy.		
3	14,130	Second (redundant) and infrared data.	Unknown.	Total loss of visible and infrared data.		
4	20,850	Photomultiplier tube #4 failed in the visible/infrared spin scan radiometer (VISSR).	Unknown.	Degraded operation of the VISSR, but no additional mission degradation because both VISSR encoders failed previously.		Anomaly discovered during spacecraft tests.
5	38,110	One side of the S-band subsystem exhibited 5 to 8 kHz frequency shift.	Unknown.	Negligible; redundant side of S-band subsystem utilized.		
6	-	X-ray reference voltage telemetry point failed.	Unknown.	Negligible mission effect.		
		GOES-3				
1	ε	One channel of energetic particle sensor noisy since launch.	Unknown.	Minor loss of space environment monitoring data.		
2	1,870	One side of the attitude determination and control subsystem failed.	Unknown.	Negligible due to redundancy; side 2 was used.		Somewhat less than one year later side 1 was found to be healthy and was used again.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-3				
3	3,960	Increasingly severe line loss in the visible/infrared spin scan radiometer (VISSR).	Lubricant build up in VISSR.	Significant and increasing data loss.		Officially declared "degraded" 7000 hours later.
4	8,610	Intermittent mirror stepping in the visible/infrared spin scan radiometer (VISSR).	Unknown.	Some degradation of VISSR operation.		
5	8,860	The solar x-ray monitor position read out and stepper operated intermittently.	Unknown.	Apparently minor.		
6	10,920	Back up encoder for the visible/infrared spin scan radiometer failed.	Unknown.	Not too serious since primary encoder still available but "roll down" of expanded frame was no longer possible.		
7	14,040	Visible/infrared spin scan radiometer (VISSR) full disk pictures stopped at approximately 1810 lines and expanded frame made lost.	VISSR torque anomaly of undetermined nature.	Minimal effect.		Problem went away three weeks later.
8	17,640	High bit error rates and degraded picture when earth sensor #2 used.	Unknown.	Negligible, since earth sensor #1 was used.		Problem later went away.
9	19,480	Hang ups in the primary encoder for the visible/infrared spin scan radiometer (VISSR) becoming progressively worse.	Due to degrading encoder bulb.	Loss of all experiment data by 23,800 hours on orbit.		VISSR officially declared a failure at approximately 25,000 hours; the spacecraft was then placed on standby status.

C-2

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		Anomalies				
		GOES-3				
10	20,590	Photomultiplier tube #4 failed in the visible/infrared spin scan radiometer.	Unknown.	Not serious.	Ground work-around developed to eliminate the resulting gap in use data.	
11	-	One solar array temperature sensor failed.	Unknown.	Insignificant.		
		GOES-4				
1	c	0.54° misalignment between spacecraft body axis and spin axis.	Design defect; spacecraft imbalance.	Negligible.		No effect during early portion of spacecraft life but misalignment is expected to increase as fuel is depleted; therefore VAS images must be corrected.
2	c	Apogee engine temperature started dropping unexpectedly.	Attributed to thermal design.	Small; engine fired at 2nd apogee instead of third successful action.	Design changed for GOES 5.	
3	c	Battery voltage did not increase when spacecraft first entered sunlight post-launch.	Unknown.	Small; batteries subsequently starting charging but it took 5½ hours to charge.		
4	c	SEM x-ray sensor does not function in earth sensor reference mode.	Due to workmanship.	System must be operated in sun reference mode to obtain SEM x-ray data.	Problem corrected on future GOES.	
5	c	SEM x-ray positioner telemetry indicates ± 0.5° error when x-ray is stepped by increments of 1 or 2 steps.	Unknown.	Not serious.		
6	c	Command decoder #1 intermittently failed to accept commands when cold (post eclipse) if command tone modulation exceeded 1 radian.	Unknown.	Not serious.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-4				
7	ε	PCM modulation interference with IRIG-B real time data.	Unknown.	Negligible.		Problem can be eliminated by adjustment to ground equipment.
8	ε	Banding in VAS IR images during eclipse season.	Attributed to design.	No impact.		
9	ε	S-band transmitter 2B temperature dropped to -28.5°C. during eclipse.	Thermal design problem.	No impact.		Qualification temperatures re-defined post launch.
10	ε	Magnetometer boom deploy telemetry point failed.	Unknown.	Not significant.		
11	ε	Design control slightly affected when switching from earth sensor to sun sensor reference mode.	Accuracy error.	Negligible.		VAS and antenna pointing slightly affected during switch over.
12	1,700	S-band transmitter #1 failed.	Attributed to design, parts, workmanship, materials.	Negligible; switched to transmitter #2.		Transmitter has not been powered since failure.
13	2,320	SEMS HEPAD solid state detector failed.	Attributed to part failure.	Significant; loss of HEPAD data.		
14	3,330	Thrust delivered by radial thrusters #1 and #2 considerably less than nominal.	Probably due to a heat soak back problem.	Negligible; RCS operational procedures modified and performance normal.		Occurred three times.
15	4,600*	Excessive VAS encoder torque buildup due to excessive lubricant.	Lubricant too thick.	Significant; VAS encoder must be continually powered which precludes use on ground of automatic control functions.		Continual problem on GOES.
16	4,800*	Spurious/phantom commands change VAS configuration.	Attributed to static discharge or floating ground.	Small, often disrupts VAS operation.		Has occurred 22 times.
17	5,250	UHF Receiver #1 (DCPR) failed.	Attributed to design.	Insignificant; used UHF receiver #2.	Pads installed on GOES 5 and F.	

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-4				
18	5,300*	S-band DCPR SNR increases about 20db daily.	Possibly due to external S-band source.	Not significant.		Condition lasts about 10 minutes and returns to normal.
19	6,690	Central Telemetry Unit (CTU) #1 failed.	Possibly due to random part failure.	Insignificant; used alternate CTU but lost 65 minutes of SEM data.		
20	8,500*	S-band transmitter #2 downlink power decreasing.	Possibly due to thick film resistor or transistors.	No impact.		Voyager used same transistors and had similar problem.
21	8,590	Abrupt loss of RF output from DCPR transmitter prior to eclipse.	Unknown.	Insignificant; returns to normal.		Has recurred several times, both pre - and post eclipse and returns to normal following ground commands.
22	10,600	Despin bearing assembly temperature exceeds predicted winter max of 32°C.	Unknown.	No impact; temperature did not reach critical point.		
23	13,700	Central Telemetry Unit #2 reset itself.	Unknown.	Insignificant; commanded back to normal.		
24	13,900	SEMS magnetometer Hp axis failure.	Unknown.	Significant; loss of magnetometer data.		
25	15,400	Solar array output dropped abruptly (0.5%, 80mA)	Unknown.	Significant; not known whether effect will be permanent.		Correlates with high level solar particle event.
26	-	Spin axis precesses during continuous axial jet firing.	Due to plume impingement on despin antenna.	No impact on mission.		
27	-	2db ripple in DCPR passband.	Unknown.	No impact.		
28	-	CDA telemetry transmitter #1 output decreased from 3.3 to 1.8 watts.	Unknown.	No impact.		

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		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-4				
29	-	Battery #1 charge current telemetry does not respond when transitioning from charge to discharge.	Unknown.	Not serious.		
30	-	UHF transmitter output higher than expected.	Unknown.	Not serious.		
31	-	VAS mirror did not stop at line 001.	Unknown.	Not serious.		
32	-	Five telemetry points are anomalous.	Unknown.	Significant; loss of data.		
		GOES-5				
1	c	VAS radiation cooler cover temperature rising slightly faster than predicted.	Unknown.	Small; deployed cover early and had 14 days instead of planned 17 days to outgas spacecraft.		
2	575	All CTU #2 digital analog data invalid.	Problem isolated to specific circuit.	Negligible; normal operation restored.		Occurred twice.
3	2.350*	Phantom commands change VAS PMT channel 7 gain.	Attributed to static discharge.	Small, commands sent to reset PMT.		
4	3,090	Demodulator #1 squelch/unsquelch telemetry point failed.	Unknown.	Small; loss of housekeeping data point.		Became operational about a month after failure.
5	4,120	RCS Fuel Tank pressure telemetry inoperative.	Unknown.	Small; loss of housekeeping data point.		
6	6,910	During normal frame size command, VAS scan mirror reversed its direction but failed to stop at the North limit.	Probably due to conflict between timing and frame size logic.	Small; loss of picture data until commanded to normal.		
7	7,510*	Shift in responsivity of 3 of 8 VAS visible detectors during eclipse season.	Unknown.	Significant; VAS visible pictures badly striped and causes loss of visible images when anomaly occurs.		Has occurred on other GOES.

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		GOES-5				
8	8,160	CTU #1 failed.	Unknown.	Negligible, used CTU #2.		
9	9,280	Solar array output dropped abruptly.	Due to high level solar particle event.	Significant; not known whether effect will be significant.		
10	-	+5 volt power supply voltage level exceeds tolerance.	Unknown.	Not serious.		
11	-	HEPAD voltage sensor very sensitive to temperature fluctuation.	Unknown.	Negligible, does not effect SEMS operation.		
12	-	VAS filter wheel position telemetry point incremented in wrong direction when command executed.	Unknown.	No effect.		
13	-	2db ripple DCPR.	Unknown.	Not serious.		
14	-	Spurious command indications.	Unknown.	Not serious.		
15	-	Battery #1 charge current telemetry saturates about half the time during high rate charge.	Unknown.	Not serious.		
16	-	Battery #2 charge current telemetry saturatos about half the time during high rate charge.	Unknown.	Not serious.		
17	-	Spin axis precession.	Due to jet impingement on despin antenna.	No impact.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		IMP-8				
1	39,000	Flipper on MESS experiment failed.	Unknown, cause not investigated.	Negligible, magnetometer sensors still usable.		
		ISEE-1				
1	e	Sunlight entered sensor of electrons and protons experiment.	Design error or oversight; sensors were light sensitive.	Caused loss of about 50% of experiment data.		
2	4,150	Ion Composition Experiment high voltage power supply failed.	Unknown.	Negligible.		
3	6,930	Detector window of Low Energy Cosmic Ray Experiment punctured.	Probably due to micrometeoroid impact.	25% data lost.		
4	10,650	Plasma Experiment high voltage control circuit inoperative at high limits.	Unknown.	50% data lost.		
5	16,340	Short in -6 volt power supply in Energetic Electrons and Protons Experiment.	Unknown.	Loss of experiment.		
6	21,360	Spacecraft required 3 to 4 hours to warm-up before commands were accepted following eclipse.	Unknown.	Commands eventually accepted and operation normal.		
7	26,320	Low Energy Protons and Electrons Experiment "A" section saturated.	Unknown.	Negligible; commands eventually accepted and operation normal.		
8	28,440	Fast Electrons Experiment high voltage power supply abnormally turned itself off.	Unknown.	Negligible.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ISEE-1				
9	29,160	ACS switched from pulsed firing mode to continuous firing mode during attempted reorientation maneuver.	Attributed to garbled command.	Negligible since subsequent maneuvers normal.		
10	31,580	Magnetometer did not respond to commands.	Attributed to "glitch".	Negligible; temporary problem which did not recur.		
11	38,610	Ion Composition Experiment power supply shutdown; could not be commanded back on.	Caused by defect in a second level power supply.	Possible partial operation; no further data available.		
12	39,450	Battery failed.	Caused by battery degradation and consequently, overpressure.	Spacecraft shutdown during eclipse; solar power adequate for spacecraft loads during non-eclipse.		Similar problem on ISEE-3.
		ISEE-2				
1	16,820	Spacecraft shutdown due to undervoltage.	Unknown.	Small; caused a 6-hour loss of data.		
2	21,500	High voltage failure in Fast Plasma Experiment.	Unknown.	Negligible.		
3	37,000	Solar Wind Experiment count rate degraded.	Due to fatigue effects in channeltron electron multiplier.	Negligible.		
		ISEE-3				
1	3,620	Gamma Ray Burst Experiment pulse height analyzer memory failed.	Unknown.	Serious loss of experiment data.		
2	4,360	Loss of pulse height analyzer in High Energy Cosmic Ray Experiment.	Unknown.	Serious loss of experiment data.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		ISEE-3				
3	11,200	Short in low voltage power supply of solar x-rays and electrons expe t.	Unknown.	Small; loss of electron portion of experiment but x-ray portion not affected.		
4	13,940	rtion of Solar Wind Experiment stopped outputting counts.	Unknown.	Possibly 50% loss of experiment.		
5	16,050	Sizable hydrazine use and spin rate changes prior to attitude maneuver.	Probably caused by bad command sequence.	Small since maneuver completed by redundant system and no re-currence of problem.		
6	22,460	Failure in solar wind instrument.	Unknown.	Negligible, since solar wind information apparently recon-structed from data from another part of the instrument.		
7	29,130	Battery voltage dropped to 3 volts (should have been 20v).	Caused by battery degradation and consequently, overpressure.	Negligible, battery not needed for present or remaining portion of mission.		Similar problem on ISEE-1.
		IUE				
1	70	Panoramic Attitude Scanner #1 failed.	Due to failure of a CMOS IC.	No effect.		
2	100+	On-board computer halts, 4k and 8k memories crash, etc.	Possibly to thermal design.	Negligible; software work-around developed.		
3	190	Camera deck temperature decrease from +10°C to +8°C.	Attributed to soft-ware error.	No effect.		
4	480	Short wavelength back-up camera grid voltage incorrect.	Due to temperature.	Negligible, use prime camera.		Camera performs properly in cold temperatures.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		IUE				
5	405*	Long wavelength camera scan failure.	Unknown.	Negligible, used redundant unit.		
6	550	Panoramic Attitude Sensor #2 does not accept commands.	Unknown.	Negligible; method developed for attitude recovery.		
7	1,320	Camera lamp did not fire.	Attributed to hot lamp.	Negligible.	Procedure changed to allow lamp to cool.	
8	1,440	Telemetry rate change command not executed.	Ground station problem.	Not serious.	Resolved by changing from right hand to left hand polarization of ground antenna.	Intermittent problem.
9	1,440	Solar Array temperatures appear abnormal.	Due to array thermistor failure	No effect on power output.		
10	3,890	Temporary loss of On-Board Computer telemetry data.	Unknown.	Negligible; problem cleared but spacecraft drifted 11°.		
11	10,700	Gyro #6 failed to start.	Possibly due to a bearing problem.	Negligible, redundancy available.		
12	15,285	Aperture problem.	Possibly caused by EMI.	Negligible; work-arounds implemented.		
13	15,790*	Long wavelength camera did not return to stand-by mode.	Problem in scan control mode.	Negligible, alternate camera used.		
14	19,900	Abnormally high start wavelength background.	Due to improper configuration of camera.	Negligible.		
15	20,800	Sporadic false/lost commands from command decoder #1.	Possibly due to correlation with Earth's radiation belts.	Negligible.		
16	21,480	Fixed rate slew command not executed.	Attributed to OBC glitch.	Not serious.		
17	25,270	Hydrazine catalyst beds #4 and #6 not heating.	Unknown.	Negligible; used another set of heaters.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		IUE				
18	26,250	Incorrect short wavelength read-out values.	Probably due to lost command by command decoder or camera logic.	Not serious.		
19	30,000	Gyro #1 gradual temperature drop.	Possibly due to a thermistor failure.	Small, unit taken off-line but probably usable in an emergency.		
20	31,100	Gyro #3 temperature drop.	Possibly due to a thermistor failure.	Negligible.		Unit performs normally but telemetry in error.
21	33,500	Loss of PCM stream from S-band antenna.	Unknown.	Negligible.		
22	35,880	Gyro #1 abnormally high rate and delta values.	Probably due to gyro feedback loop open.	Small, lost redundancy.		
23	37,200	Gyro #5 gradual temperature increase.	Unknown.	Small effect; degraded performance.		
24	39,400	Gyro #2 failed.	Unknown.	Negligible, redundancy available.		
		LANDSAT-2				
1	27,200	Sun sensors partially ineffective.	Due to high beta angle.	Small, degraded SAD tracking but returned to normal after a couple of weeks.		
2	28,100	Array degradation was 22.2% at the end of 39 months in orbit (higher than expected).	Unknown.	No effect.		
3	31,500	Array current notching.	Attributed to sets of parallel solar cells with intermittent electrical connections in an area of probable high temperature.	Negligible.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
		LANDSAT-2				
4	34,758	VHF receiver output briefly abnormal while loading ECAM.	Unknown.	Negligible.		
5	34,886	Narrow band tape recorder #1 failed.	Unknown.	Negligible; NBTR #2 used.		
6	37,305	RMP-2 motor current began running high.	Unknown.	Negligible, RMP-1 turned-on.		Later indications show high friction present.
7	39,100	Infrequent occurrences of MSS missed line starts.	Unknown	Negligible, scan monitor switched to 3 source.		Occurred on Landsat-3.
8	41,956	Yaw flywheel failed.	Possibly due to lubrication of bearings supporting the flywheel.	Very serious; caused loss of spacecraft but operation later restored.		Possible redistribution of lubrication allowed reactivation.
9	46,712	WBVTR #2 failed.	Unknown.	Significant, loss of all wideband stored data.		
10	45,464	NBTR #2 failed to play back until the 3rd playback attempt.	Unknown.	Small, operation restricted to recording 1 orbit per day of "health" data on the last half of the tape.		Occurred several times.
11	49,770	Telemetry excitation line failed open.	Unknown.	Negligible, not critical to spacecraft operation.		
12	53,184	Decrease in solar array output, increase 2 months later, decreased again 3 weeks later.	Unknown.	Small, restricted payload operation.		
13	58,155	OAS solenoid closed properly on command but re-opened anomalously.	Possibly due to noise.	Negligible; operated properly on second command.		
14	61,390	Unencoded C11 command via VHF disabled ECAM.	Unknown.	Negligible, ECAM properly enabled again.		
15	61,390	Yaw flywheel stopped again for about half orbit.	Unknown.	Negligible, recovered normal operations.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		LANDSAT-2				
16	62,665	Command clock power supply #2 failed.	Unknown.	Small, switched to redundant power supply but only 1 command link now open.		
		LANDSAT-3				
1	ε	Left solar paddle did not slew as expected at deployment.	Possibly due to shadowing of sun sensor.	Negligible; slight deployment delay.		
2	ε	Higher spacecraft disturbance torques than expected.	Unknown.	Insignificant.		
3	76	COMSTOR-B, cell 4 failed to verify and execute a command.	Unknown.	No effect.		Cell 4 was commanded to zeroes and was no longer used.
4	95^+	RBV camera #1 intermittent white level saturation.	Unknown.	Negligible; did not interrupt RBV operation.		
5	264	COMSTOR-B, cell 4 changed from all zeroes to all ones.	Unknown.	Negligible, redundant COMSTOR-A used.		COMSTOR-B returned to service at 2976 hours.
6	600	Small percentage of MSS processed pictures have random patches of "salt and pepper".	Unknown.	Not serious.		
7	1,440	ECAM halted due to a fixed core checksum error.	Attributed to bit failure in core location.	No effect.		Checksum modified to accommodate the error
8	$1,600^+$	MSS band 5 degradation, no video sensor 25 video output on band 5, and degraded output from sensor 26.	Attributed to contamination from residual gas molecules.	Significant; loss of IR data.		Periodic outgassing performed to clean sensors but not successful in long run.
9	3,190	SMART #6 fired on analog end of tape detection for WBVTR #1.	Unknown.	Not serious.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		LANDSAT-3				
10	3,260	SMART #4 and 5 fired on digital end of tape detection for both WB tape recorders.	Caused by inadvertent tape recorder operation to end-of-tape.	Not serious.		
11	3,387	SMART #2 fired.	Due to high headwheel current on WBVTR #1.	No effect.		Subsequent tests showed normal current.
12	3,800*	MSS missed/late line starts.	Cause unknown.	Significant overall loss of data.	Switch to scan monitor light source B temporarily resolved problem but re-curred.	
13	4,300	APU time code to MSS rollover of 10th's and 100th's of a second occurred a few milliseconds earlier than rollover of the even second.	Unknown.	No effect.		
14	4,300	WP power amp #2 low values for helix current and collector temperature.	Unknown.	No effect.		
15	5,497	SMART #6 tripped on end-of-tape protection.	Trip legitimate.	No effect.		
16	5,954	SMART #7 fired on end-of-tape detection for WBVTR #1.	Due to high head-wheel current on WBVTR #1.	No effect.		
17	6,145	Low unregulated voltage.	Due to simultaneous playback of MSS and RBV during space-craft night, thus discharged batteries to low level.	Small effect.	Mission planning instructed not playback both payloads at night.	
18	6,720*	MSS extra scan monitor pulses cause early line starts or extra end-of-line codes.	Occurs over magnetic anomalies.	Little impact.	Landsat's 1 and 2 had similar occurrences.	

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		LANDSAT-3				
19	8,000	LSAD motor winding voltage and temperature gradually increasing.	Possibly due to friction buildup in the 2nd or 3rd stage gear reduction.	Negligible.		
20	10,500	RMP-2 input current increased and spikes occurred on telemetry.	Unknown.	Negligible, RMP-1 used.		RMP-2 returned to normal 10,600 hrs.
21	10,913	Playback of MSS data on WBVTR #1 noisy.	Unknown.	Significant, WBVTR #1 subsequently used only for playback of RBV data.		
22	14,980	Momentary Rear Scanner glitches.	Possibly due to RFI.	Small, rear scanner returned to normal.		
23	17,580	Right solar panel temperature abnormally high.	Attributed to failed telemetry circuit.	No effect.		
24	18,500	Non-authorised CIU commands.	Possibly due to noise from VHF system.	Not serious.		
25	20,747	ECAM halted when S-band timer reset commanded.	Possibly due to timer reset command.	Negligible. ECAM restarted and normal operation resumed.		
26	21,840	Abnormal solar array current notching.	Unknown.	No effect.		Similar situation observed on Landsats 1 and 2 as seasonal variation.
27	24,378	All MSS sensors suddenly failed to transmit quantum levels between 1-7, 9-15, 33-39, 41-47.	Probably open circuit or failed component in MSS multiplexer.	Small, loss of 3 months of data.		
28	29,361	Short circuit in command matrix A drivers.	Unknown.	Negligible, work-around developed.		
29	31,626	WBVTR #1 failed when commanded to fast forward mode.	Due to either broken tape or jammed gears.	Significant. data acquisition severely limited.		WBVTR #2 continues to be used for MSS and RBV data when required.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		LANDSAT-3				
30	32,500	MSS line length occasionally varied by 2 or 3 pixels.	Unknown.	Small, ground work-arounds being attempted.		
31	33,000	MSS occasional missed end-of-line codes.	Unknown.	Negligible; normal operation restored by switching from scan monitor A to B.		
32	34,526	SCAN halted.	Attributed to an illegal word getting into memory.	Insignificant.		
33	36,700	RBV Camera #2 subscene was 20-30% white background.	Caused by intermittent improper shutter closure.	Significant loss of RBV data.		
		LANDSAT-4				
1	c	Ku-band antenna will not deploy.	Unknown.	Very serious, but follow-up antenna movement attempts successful.		
		MAGSAT				
1	c	Design occurred approximately 4 minutes late; only one of two timers functioned.	Possibly due to higher than expected thermal resistance between the fourth stage and the timer.	Negligible.		
2	c	Coarse sun sensor data not decodable.	The cause could have been a hardware or algorithm problem; or the circuitry may have been miswired.	No serious mission effect since other attitude data were available.	A special model was derived for application to the mission.	
3	c	One scalar magnetometer lamp (of two) required slightly more RF power on orbit than in ground tests.	Unknown.	Negligible.		

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		MAGSAT				
4	6	Drift track of spacecraft pitch axis exhibited an unpredicted tendency.	Unknown.	Apparently not serious.		
5	12	Intermittent noise in the lamp excitation circuitry of the Scalar Magnetometer.	Caused loss of lock in the tracking filters.	Attributed to some kind of feedback from the power supply.	Loss of 70-80 percent of scalar magnetometer data but little mission effect since the vector magnetometer provided sufficient information.	
6	20	Internal temperature of base module about 10°C higher than expected.	Essentially unknown, but possible loss during launch of thermal panel/shield around the IR scanner on the base of the spacecraft.	Progressively severe degradation of power supply from inability to charge battery.		
7	250	Loss of star camera data for periods of 30-40 minutes.	Direct sunlight on the sides of the sunshades penetrated their black plastic skin.	No effect on mission objectives.		
		NIMBUS-4				
1	-	Nimbus-4 turns twice per orbit.	Unknown.	Negligible.		
2	61,106	Battery 4 turned off.	Unknown.	Negligible.		Batteries 2 and 7 (of 8) already turned off.
		NIMBUS-5				
1	37,824	NEMS channel 5 off full-time; channel 4 off as required for power magnagement.	Unknown.	Partial loss of data.		
2	59,000	Batteries 4 and 6 (of 8) turned off.	Unknown.	Negligible, because of earlier failure.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-5				
3	60,290	HDRSS-B exhibited short playbacks.	Unknown.	Loss of some stored data.		
4	60,900	HDRSS-B (tape recorder) returned to normal operation.	Unknown.	No adverse effect; portion of end-of-tape not being used.		
5	69,430	HDRSS-A data became noisy.	Partially due to tape flutter and wow.	Loss of some stored data.		Attempted to fine tune ground stations to accommodate increased flutter and wow.
6	71,165	Prime CONSTOR went into illegal mode many times during 1 pass.	Attributed to Y-enable pulse being to short.	Loss of 1 orbit of ESMR data.	Afterwards ground station work-around.	Has happened before.
7	71,550	HDRSS-A failed; tape did not move.	Unknown.	Non-real time data collection restricted to Tape Recorder B.		
8	84,300	HDRSS-B failed; no modulation.	Probably due to broken belt or tape.	Significant; space craft restricted to real time data acquisition only.		Loss of ESMR Antarctic coverage for the Navy.
		NIMBUS-6				
1	12,000	ESMR horizontal channel failed.	Unknown.	Small; partial loss of ESMR data.		
2	15,770	THIR radiometer motor failed.	Unknown.	Small; loss of THIR instrument.		
3	15,660	ERB scanhead locked at NADIR view.	Unknown.	Small; partial loss of ERB data.		

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-6				
4	.5,823	Average yaw wheel motor drivers duty cycle exceeded 20%.	Unknown.	Negligible, returned to normal.	A positive 12-second charge placed on momentum pitch coil and duty cycle returned to average 5% range.	
5	42,426	Prime COMSTOR switched out of verify mode into indeterminant mode.	Unknown.	Not serious.		
6	50,068	HDRSS-B failed.	Unknown.	Serious, limits Nimbus-6 to real time data acquisition only.		
7	50,447	Apparent NIM-5 sequence was found in COMSTOR NIM-6 location.	Unknown.	Not serious.		
8	55,460	Battery #6 lost its capability.	Unknown.	Serious, causes remaining 7 batteries to become overcharged and too hot.	Work-around being developed.	
		NIMBUS-7				
1	ε	Use of CZCS threshold on mode causes loss of data in CZCS channels 1-4.	Unknown.	Small, reduced water coverage from 90% to 50-60%.		
2	ε	CZCS data taken within ±10° of solar equator worthless.	Due to sun glint.	Small, data no longer collected in the area of ±10° of the solar equator.		
3	40	SAMS lens temperature increased to 53°C.	Due to erroneous thermal mold.	No effect, lens heaters were turned off.		
4	57	SAMS; interference on data channels and chopper amplitude.	Due to type of detectors used for the data channels.	No effect; problem was expected.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
5	185	TOMS high voltage dropped 25% for 1 data frame and 2 disturbances on TOM PMT output for this frame.	Unknown.	Negligible.		Was seen in test.
6	346*	SBUV output drops to zero for 1 sample during solar calibration in continuous scan mode.	Unknown.	Negligible.		Dropout appears to be level sensitive.
7	370	Only 1 memory unit in the SAMS PCL accessible.	Attributed to internal logic fault that prevents switching between memories.	Small; memory must be reloaded for each new scan pattern.		Problem could have existed pre-launch; loading both memories with different programs had not been tested.
8	405*	CZCS data dropout on channel 4 data.	Unknown.	Not serious.		Occurs randomly in real time data operations with high gain and threshold off.
9	490	After activating SAMS cooler, detector cooled to only 165°K.	Unknown.	Small; performance adequate.		
10	675	VIP telemetry glitches when CZCS DC restore for any channel goes to positive.	Unknown.	Not serious.		
11	to 700	Spacecraft attitude disturbance at CZCS scan turn-on and turn-off.	Unknown.	Negligible; within allowable roll rate amplitude.		This was expected.
12	1,040	ERB solar assy, moved 2° right on a 1° right command.	Unknown.	Small; requires 2 commands be sent.		
13	1,193	SAMS scan shifted 43 counts, cell 43 changed from command 557 to zero, PCL program shifted to a new location.	Unknown.	Small, problem has not recurred.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
14	1,194	SAM II power on/off status telemetry monitor erratic.	Unknown.	Small; causes some problems in ground computer housekeeping data processing.		
15	1,542	Degradation of ERB scanning channel #18 output.	Unknown.	Small; channel 18 data, direct measurement of earth flux, unusable but other data used to derive earth flux.		
16	1,700 to 3,000	Difficulties with execution of real time commands and COMSTOR loading.	Unknown.	Small, resulted in several orbits with no SAM II operation.		
17	1,700+	ERB scanhead went into a forbidden zone.	Attributed to gimbal motor torque margin and lubricant viscosity and later to gimbal slew malfunction.	Negligible.		
18	1,760 to 2,668	Commands did not execute.	Possibly due to a clock race condition.	Not serious.		
19	1,837	SBUV/TOMS signature of continuous scan data telemetry changed.	Unknown.	Not serious.		Occurs during earth night/non-scan period.
20	2,100	DSAS sensor 2 elevation decreases from 4.8 TMV to 4.0 TMV and elevation position levels out at 160 counts for about 1 to 2 extra samples.	Unknown.	Not serious.		Correlates with solar incidence angle.
21	2,375	ERB scan did not go on when commanded following a scan routine change.	Unknown.	Small, scan routines 3 and 4 no longer used; scan routine 5 is now SOP.		
22	2,773	ERB channel 18 went from occasionally noisy to full time noisy.	Unknown.	Small; ERB channel 18 data not usable.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
23	3,530	3 commands failed to execute from redundant COMSTOR.	Unknown.	Not serious.		
24	4,189*	ERB scan angle encoder output showed sharp drop.	Unknown.	None, has not effected data collection.		
25	4,520*	SAMS limb scan went to an illegal stop.	Unknown.	Negligible; reloaded PCL and continued with normal operation.		
26	4,763	SAM II; 4 count variation in RVCT analog telemetry monitor.	Unknown.	Negligible, does not effect SAM II data or operations.		
27	4,777	CZCS channel 5 output occasionally low.	Due to DC restore problem.	Small.		
28	4,800	240ma notch in array current occurs every orbit at 25 minutes; after spacecraft night to day transition.	Unknown.	Small effect.		Problem was essentially negligible to start with; later (orbit 4200) observed 90% of the time and caused reduced CZCS operating time.
29	5,235	LIMS lost lock on the limb.	Due to increased detector temperature caused by depletion of the cryogen methane.	Small.		LIMS was turned off on Orbit 3,09? after 4,865 operating hours (turned off permanently).
30	5,242	Battery #4 high charge/ load sharing relative to other batteries.	Due to newer Battery 4 mismatched with other older batteries - problem expected.	Negligible.	Periodically turn off Battery 4 so charge/ discharge sharing balanced for other batteries.	
31	5,337	Tape recorder #1 stalled in record mode at BOT +5 minutes, recovered, later had data dropouts.	Unknown.	Negligible.	New procedure instituted to use only the middle of the tape, lose 65% of tape.	

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
32	5,576	Unable to command TOMS high voltage on.	Unknown.	Negligible.	Finally turned on after many attempts.	Now left on continuously.
33	5,600*	SAM II; whole disk of sun not in fov at sunset.	Attributed to S-band antenna getting into fov.	Negligible.		Involves apparent shadowing of SAM II azimuth sunsensors.
34	6,391*	Commands did not execute.	Attributed to clock-race problem.	Negligible.		
35	6,741	CZCS channels 1-5 showed 4 step decrease during calibration.	Possibly due to calibration lamp #1.	Negligible; used calibration lamp #2.		
36	7,096*	Could not acquire spacecraft though spacecraft receiver AGC levels adequate.	Possibly due to CDIU current.	Small, operational procedures implemented to circumvent problem.		
37	7,106	CZCS channel 6 detector temperature.	Unknown.	Negligible.	Decontamination cycle performed which corrected problem.	
38	7,429*	SMMR channel 1 crystal current monitors showed decrease counts.	Indicative of drop in output of Gunn diode oscillator.	Negligible.		
39	10,696	Left SAD housing pressure drops.	Attributed to leak in metal bellows assy.	Negligible, did not result in voltage or current changes.		Could eventually allow lubricant to leak and result in binding of bearings.
40	11,788	SMMR channel 1 output and calibration data went to full scale for about 30 seconds.	Unknown.	Not serious.		
41	11,790*	1 frame drop-out on tape recorder #2 near BOT in playback.	Unknown.	No significant loss of data.		
42	12,150	SAM PCL jumped into unscheduled calibrate and then back.	Unknown.	Negligible; PCL was reloaded and no further problems.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
43	13,125	ERB failed to go to long-wave check position as commanded.	Unknown.	Not serious.		
44	14,538	ERB chopper stopped rotating.	Unknown.	Small, caused loss of ERB scanning channel.		Operation normal in non-scan, nadir view.
45	15,725	Solar array output dropped 30%.	Caused by solar eclipse.	Negligible, returned to normal following eclipse.		
46	16,572	Transponder downlink turned-on spontaneously.	Unknown.	No effect.		
47	17,158	SAMS limb LVDT telemetry output became erratic after instrument placed in standby mode.	Due to input to LVDT counter floating in the standby mode.	No effect.		Had been seen in test.
48	19,295	Manifold pressure increased out-of-limits following simultaneous firings of + pitch and - roll.	Unknown.	Negligible, returned to normal within 1 orbit.		
49	24,000	Intermittent instances of receiver interference.	Unknown.	No effect.		Concentrated in S.E. Asia area.
50	25,690	Tape Recorder #2 showed a 12.5 minute gap on playback.	Possible due to foreign object between tape and heads.	Small.		Recorder positioned to bypass the "gap" area.
51	27,890	SAM II changed from fast scan mode to slow scan mode before fast scan completed.	Attributed to instrument seeing some kind of reflection.	No effect.		
52	28,905	TOMS chopper motor current dropped.	Unknown.	No apparent effect.		
53		VIP subsystem - all analog telemetry went to .4 TMV level for 32 minutes.	Possibly due to Analog MUX and/or A/D converter.	Negligible, problem went away.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NIMBUS-7				
54	-	Squib firing required re-firing for LIMS methane squib, SMMR squib, CZCS.	Unknown.	Small, squibs fired after repetition of firing commands.		
55	-	ERB scanning interferes with LIMS limb scanning.	Possibly due to structural resonance structural transmission.	Small, ERB scan operation placed on 2 out of 4 day duty cycle.		
56	-	Ground receivers unable to lock on to 4kbps VIP when transponder modulated with 25 kbps DIP data.	Ground station problem.	Small.		
57	-	Unexpected high temperature of CZCS cooler door and cone due to door heater.	Possibly due to higher earth albedo in orbit than was simulated in thermal/vac.	No mission effect.		
58	-	Digital solar aspect sensor; small errors for brief periods (occasional 3 count jump in azimuth).	Unknown.	Not serious.		
59	-	Real time commands and COMSTOR loading commands not executed properly.	Possibly due to race condition between incoming command and internal command clock timing.	Negligible.		
60	-	CZCS channels 1-4 gain less than expected.	Unknown.	Not serious.		
61	-	SMMR cold horn views the sun every orbit.	Design problem.	No mission effect.		

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		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NOAA-4				
1	28,700	Scanning Radiometer #1 failed.	Unknown.	Small		
2	29,180	Scanning Radiometer #2 failed.	Unknown.	Small		
3	34,000	Spacecraft occasionally reads spurious commands during noisy periods.	Unknown.	No damage.		
4	34,600	VHRR #2 failed.	Unknown.	Significant; loss of instrument.		
		NOAA-5				
1	13,320*	Scanning Radiometer #1 failed but restarted and operated normally (mirror stopped).	Unknown.	Small; restart as necessary by "kicking".		Exhibited fail-restart pattern; no further info if it has been restarted since last failure.
2	14,280*	Scanning Radiometer #2 failed but restarted and operated normally (mirror stopped).	Unknown.	Small, loss of instrument.		Restarted by "kicking" after each failure but at last failure (19,960 hours) turned off radiometer.
3	18,720	Scanning Radiometer Recorder #1 data noisy and unusable.	Unknown.	Negligible, scanning Radiometer Recorder #3 used.		
4	18,720	Scanning Radiometer Recorder #2 data noisy.	Unknown.	Small, used SRR#3.		
5	18,880	DDP data on tape recorder noisy.	Unknown.	Negligible; used redundant unit.		
6	19,000	Minor limitations in VHRR tape recorder.	Due to varying lengths of time code.	Minor.		
7	21,360	VHRR tape recorder failed.	Unknown.	Significant; VHRR data available in real time.		

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		NOAA-5				
8	22,100	Scanning Radiometer Recorder #3 would not playback.	Due to time base unit being reset without re-selection of Recorder #3.	Small, returned to normal.		
		NOAA-6				
1	ε	Large spacecraft disturbance and attitude perturbation just post-launch.	Probably due to thrust developed by flow of hydrazine propellant.	Small, no permanent degradation to spacecraft.		Also occurred on TIROS-N and the USAF DMSP spacecraft.
2	ε	CPU #1 indicated "not ok" at initial contact.	Due to timing switching problems at handover from boost mode.	Small; CPU #1 forced back to "ok" status and operated normally.		
3	ε	One thermistor on Rocket Engine Assy #2 indicated saturation or full scale reading.	Unknown.	Negligible, returned to normal.		
4	ε	Skew gyro replaced the z gyro in the gyro use matrix.	Probably due to spurious switching.	Negligible, system acted acted normal.		
5	ε	Analog telemetry channels 303 and 277 are reversed.	Apparently due to a wiring error.	Negligible.		Corrected in software.
6	ε	SAD command mode changed from normal mode to complement mode.	Unknown due to lack of data.	No effect on spacecraft.		
7	ε	Spacecraft attitude shift of 0.1° in pitch and roll when sun-moon flag set for 2 quads of the ESA.	Due to ACS algorithm assuming spherical earth instead of real ellipsoid.	No effect.		
8	ε	Hydrazine components run hotter than expected in 100% sun.	Possibly due to contamination from the apogee motor burn.	Negligible.		
9	380	Small difference between the readings of the 4 platinum resistive thermistors in AVHRR backscan housing.	Due to thermal gradient.	Not serious.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NOAA-6				
10	600	Nitrogen latching valve temperature almost doubled, then returned to normal.	Unknown.	No effect.		
11	720	MSU channel gains and crystal currents took longer to stabilize than expected.	Unknown.	Data quality not effected.		
12	3,380	MSU crystal current decrease and space count increases at a rate of 4-5 counts per day.	Due to poor design of an attenuator in a local oscillator circuit.	Small, causes MSU channel 3 gain decrease.		Would degrade the instrument if it got worse.
13	3,640	Faulty DTP4A pressure sensor.	Unknown.	Small, incorrect telemetry point.		
14	7,650	Temperature bias shift of about 0.5° per hour in skew gyro.	Unknown.	Small, caused incorrect yaw update but workaround used.		
15	7,990	Excessive bit error rates and data drop-outs from DTR-2A.	Unknown.	Negligible, redundancy available.		DTR-2A taken out of service.
16	13,510	DTR-3A started exhibiting noise.	Unknown.	Small, tape recorder still usable.		
17	15,040	AVHRR channel 3 becoming increasingly noisy.	Unknown.	Negligible, data still usable.		
18	15,400+	DTR-2B began a pattern of loss of sync lock and slow data starts.	Attributed to low leakage resistance in lock-up capacitor C10.	Small, initially not serious but eventually taken out of service.		Data collection function taken over by NOAA.
19	18,670+	AVHRR excessive scan motor jitter, loss of sync.	Attributed to normal aging.	Small, normal operation returned after each occurrence.		
20	19,240	Uncommanded 4 level increase in TED electron/proton high voltage power supply.	Unknown.	Negligible, commanded back to normal.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NOAA-6				
21	21,120	Roll gyro exceeded stability specification.	Unknown.	Negligible, back-up gyro used.		
22	23,300	AVHRR electronics current and 6.2v reference dropped, temperature changes, scan motor current intermittent erratic mirror movement.	Due to failed CKR06 ceramic capacitor in Logic Register Circuit, but "self heals".	Small, problem comes and goes.		Capacitor identified as problem before launch.
23	26,110	Increasing attitude errors.	Unknown.	Negligible, yaw gyro was commanded out and the roll gyro back in.		
		NOAA-B				
1	c	Spacecraft did not attain operational orbit.	Malfunction in the Atlas booster caused thrust reduction			
		NOAA-7				
1	c	DTR-4A failed to playback.	Unknown.	Negligible, redundant units available.		
2	c	AVHRR earth shield door slow to deploy.	Possibly due to mechanical hang-up.	No effect.		
3	c	Magnetic coil unloadings not completely effective.	Attributed to higher than expected torque from solar pressure.	Small effect.		Yaw "X" -axis wheel-speed is unloaded with nitrogen firing on a once-a-day basis.
4	c	TIP clock 1 second ahead of command clock.	Unknown.	Negligible; compensated by ground processing.		
5	c	After rate maneuvers, regulated nitrogen pressure increased to 661 psi in a few seconds; held for 23 seconds then decreased to 535 in 20 seconds.	Unknown.	No impact.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		NOAA-7				
6	330+	Command receivers stay in operate mode continuously rather than reverting to standby.	Suspected cause is poor coax cable fabrication workmanship in SEM.	Negligible.	Repaired at NOAA lab.	
7	1,530+	Array drive electronics baseplate temperature higher than expected; exhibits continuing upward trend.	Unknown.	Small; temperatures decreasing, possibly due to declining sun angle.	—	Contingency plans for loss of SAD developed.
8	2,350	ESA Quad 2 space detector views sun once each orbit.	Unknown.	Small.		Causes small attitude transient for about 2 minutes in roll-and-pitch.
9	2,850+	Uncommanded configuration changes in SEM TED.	Unknown.	Negligible.	Commanded back to normal but command correction must be timely to prevent data loss.	Similar to incident on NOAA-6.
10	4,580	SSU lost sync on at least 3 occasions.	Unknown.	No significant impact on data.		
11	5,350	Herringbone pattern in AVHRR channel 3 pictures.	Caused by power/signal ground coupling.	No significant effect.		Similar to problem on NOAA-6.
		SMM				
1	c	Soft x-ray polychromator FCS detectors #1 and 4 suffer minor high voltage breakdown during turn-on.	Unknown.	Negligible.		Detectors stabilized but detector #1 not used extensively.
2	c	Ultraviolet spectrometer/polarimeter unplanned raster power-down and other mysterious partial power-downs inside the instrument.	Unknown.	Negligible.		May be related to EMI generated in detector #2 during breakdown.

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMM				
3	<	Coronagraph/polarimeter vidicon beam not blanked off properly during retrace.	Attributed to sensitivity of vidicon blanking circuitry to the high temperatures resulting from continuously "on" power.	Small	Cycling vidicon power for 20 minutes per orbit removed the artifacts in science images.	
4	<	Intermittent high count rates indicative of internal arcing in soft x-ray polychromator instrument.	Due to internal water vapor.	Negligible.	Propane detectors were turned off to allow venting.	
5	<	Fine pointing sun sensor #1 biased by about 4 arc-minutes from the instruments.	Software error.	Negligible.		
6	<	Hard x-ray burst spectrometer detectors and low voltage converter temperatures lower than expected at turn-on.	Unknown.	Negligible, instrument warmed up ok.		
7	<	3 Active Cavity Radiometer Sensors showed upward drift.	Attributed to attenuation of solar flux due to water evaporation from spacecraft.	No effect.		
8	400	Soft x-ray polychromator FCS drive encoder bulb failed open.	Possibly due to generic cause.	Negligible, "B" system available.		
	400	Soft x-ray polychrometer thin window high voltage flip flops spuriously reset during orbit night	Unknown.	Negligible, procedure implemented to turn the detectors off at night.		Occurred 26 times.

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMM				
10	450	Random 0.3 amp pulses on pulse load bus and quiet load bus.	Unknown.	No effect.		
11	480	Microprocessor in the hard x-ray imaging spectrometer shuts down about once per day in slave unit.	Possibly due to internal flare mode software becoming confused with rapid flare threshold level changes.	No problem as long as master microprocessor is running.		Unit finally failed; see Anomaly #20.
12	500	Soft x-ray polychromator major glitch during orbit night turned off FCS microprocessor and propane detectors high voltage, changed raster motor positions, switched from RIU clock to internal clock, lowered +5 V bus, ruined FCS analog MUX data.	Unknown.	Negligible.		May be part of Anomaly #9.
13	550	Soft x-ray polychromator FCS detector #8 shows increasing gain indicative of a leak.	Unknown.	Negligible; data normal after high voltage setting reduced.		
14	620*	C and DH clock jumped forward by 1 hour, 9 minutes over South Atlantic anomaly.	Unknown.	Negligible, corrected via software.		
15	810	UV spectrometer/polarimeter instrument high count rate from detector #2 led to unscheduled shutdown of power converter.	Attributed to breakdown of detector.	Small, detector #2 no longer used on a regular basis.		
16	1,150	Selected guide stars were lost by the on-board computer and caused a roll error of 3.5°.	Unknown.	Negligible; spacecraft was command back to proper attitude and correct guide stars reacquired.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMM				
17	1,295	Intensity level of both fine pointing sun sensors degrading with time, cause on-board computer to put spacecraft into night mode during orbit day.	Unknown.	Negligible, software changed to provide more frequent calibrations and adjustment of threshold.		
18	2,320	Spacecraft lost the sun during a slew maneuver.	Caused by software "bug".	Negligible, spacecraft commanded back to sun center.	Software presumably corrected.	
19	2,330	Radiation sensitivity of microprocessor random access memory causes random state changes over South Atlantic Anomaly (in C and DH)	Unknown.	Small, some loss of instrument data due to equipment turn-offs.	Work-arounds developed.	
20	2,450	Hard x-ray imaging spectrometer microprocessor #2 failed.	Hardware failure.	Negligible.		
21	2,590	Star tracker #1 data showed 2 stars in view due to star number not switching in telemetry.	Probably due to software error.	Apparently no impact.		
22	3,480	HAO tape recorder segment counter bit 29 stuck.	Due to a part failure.	Small, ground system software changed to work-around.		
23	3,480	Telemetry and clock out-of-sync.	Unknown.	Negligible, commanded back to normal.		
24	3,640	Monitoring software were indicated fatal error in coronagraph/polarimeter.	Possibly due to software problem.	Negligible.		
25	3,720	Soft x-ray polychromator raster drive stepper motor occasionally fails to complete a step when commanded.	Unknown.	Negligible, back-up motor available.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMM				
26	3,800	Systematic slow shift of 10-15 arc seconds and back in pitch during last 10 or 12 minutes of spacecraft day.	Possibly due to multiple reflections of earth albedo getting into Fine Pointing Sun Sensor field of view.	Negligible, software workaround developed.		
27	4,080	During on-board pitch and yaw updating, the gyro angle error was not included.	Could be software or hardware problem.	Negligible.		
28	4,120	Roll budgets updated while guide stars occulted.	Could be software or hardware problem.	Negligible.		
29	4,250	Hard x-ray burst spectrometer micro-processor #1 failed.	Unknown.	Negligible, redundant unit available.		
30	4,560	Gyro C failed.	Attributed to transient radiation susceptibility of complementary MOS semi-conductor in the electronics.	Small, control regained and Gyro B used.		
31	4,600	C/P vidicon experiences intermittent read out lock-ups.	Possibly due to degradation in parts in erase, expose and read-out control circuits.	Small severely limits use of instrument.		
32	5,760	Soft x-ray polychrometer BSC "micro" hung up.	Unknown.	Negligible.		Not clear if "micro" is microprocessor or microcode.
33	6,570	Roll reaction wheel lost.	Due to fuse design.	Small.		
34	6,580	Soft x-ray polychromator solenoid valves incorrectly disabled.	Unknown.	Small.		Raster commanded to a "sit and state" position.
35	6,760	Yaw reaction wheel lost.	Due to fuse design.	Small, skew wheel switched to yaw and roll allowed to drift.		

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMM				
36	7,220	Pitch reaction wheel lost due to fuse failure.	Due to fuse design	Significant, spacecraft no longer useful for scientific data collection.		
37	7,870	Erratic torquer bar telemetry and torquers not responding correctly to commands.	Unknown.	Negligible		
38	12,200	High Gyro-B motor current.	Unknown.	Negligible.		
39	12,400	Problem in Tape Recorder B.	Unknown.	Negligible.		
40	-	Decrease in sensitivity by a factor of 200 in uv spectrometer in Lyman-alpha range.	Unknown.	No effect.		
41	-	On certain fast motions, x-ray polychromator unpowered raster cam Z_b auto rotates.	Unknown.	Not significant		
42	-	Spacecraft disturbances of up to 3 arc-seconds at x-ray polychromator FCS raster flyback.	Unknown	Not serious.		
43	-	X-ray polychromator outer thermal shield unexpected rise to 76°C.	Unknown.	Negligible, eventually stabilized.		
44	-	UV spectrometer scatter.	Due to solar structure.	Minor.		
45	-	UV spectrometer sensitivity at short wavelength showed substantial degradation.	Unknown.	Negligible, sensitivity still adequate.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SMS-1				
1	42,575	S-band receiver #1 reduction in RF power.	Unknown.	Small.		Caused degraded VISSR data; receiver no longer used.
2	51,600*	VHF transmitter has drop-outs in downlink.	Temperature related.	No mission effect.		Problem resolved after transmitter warmed up.
3	51,980*	S-band transmitter #1 reduced power output.	Unknown.	Significant, payload data no longer available.		
		SMS-2				
1	27,060	S-band Transmitter anomaly.	Unknown.	Small, wide band picture data not possible.		
2	27,110	VHF RF power telemetry point failed.	Unknown.	Minor; some inconvenience to ground station.		
3	52,360	VISSR back-up encoder failed.	Probably due to blown encoder bulb.	Negligible, primary unit used.		
4	56,900	VISSR primary encoder failed.	Probably due to short circuit in the encoder.	Significant; loss of VISSR data.		After this failure, spacecraft used only as a repeater for GOES-5 VISSR, DCS, and WEFAX data.
5	-	Two solar array temperature sensors failed.	Unknown.	Not significant.		
6	-	Battery #1 discharge current telemetry sensor failed.	Unknown.	Not significant.		
7	-	Possible reaction control system blockage suspected.	Unknown.	Small		Due to concern over possible unequal fuel depletion causing spacecraft misalignment, no N-S changes were performed.

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remark
		SMS-2				
8	-	S-band low power mode prohibited.	Possibly due to ground station or earlier anomaly.	Small.		
		TIROS-N				
1	ε	Degraded output from one of the earth sensor quadrants causes small attitude excursions whenever one of the quadrants is temporarily disabled by the software because of sun interference.	Due to open detector in 1 quadrant; attributed to lead bond contamination due to dirty masks or some other process control deficiency.	Negligible.	Correction put into on-board software.	
2	ε*	Battery bus current oscillation in taper charge mode.	Cause unknown but somehow related to battery charge circuit.	No significant effect on mission.		Precludes trickle charging, eventually caused noise on AVHRR 3.5 micron channel.
3	ε	AVHRR baseplate and SSU baseplate temperatures stabilized above predicted temperature.	Attributed to improper thermal mode and too small a AVHRR radiator.	No effect on mission, both baseplates below allowable upper limit of 30°C.		
4	ε	Loss of attitude control; lost array orientation to the sun; battery voltage dropped to 18 volts; spacecraft began rolling and tumbling.	Attributed to failure of hydrazine system "B" nut; hydrazine leak due to probable relaxation of "B" nut because of pyro shock.	Small, nitrogen system counteracted tumble until stability regained and then momentum wheels took over.	On subsequent spacecraft, hardware modifications implemented and procedures instigated to check torque on "B" nut at launch pad.	
5	ε	Reaction support structures and hydrazine temperatures high.	Due to improper thermal design and contamination of surfaces by apogee motor.	No mission effect.	On subsequent spacecraft, contamination shields were installed and 6 additional temperature sensors were provided to better map thermal performance of the RCS.	
6	ε	Telemetry indicated heaters on and louvers open simultaneously.	Caused by leakage current in the thermal control electronics going to a worst case condition.	No effect on mission.	On subsequent spacecraft, the set point dead band widened.	

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		TIROS-N				
7	ε	HIRS/2 cooler door opened at shroud jettison.	Due to design.	No mission effect.	On subsequent spacecraft, the latch was redesigned and special pre-launch handling requirements instituted.	
8	ε	No data output from SSU channel 3.	Cause unknown.	Small, loss of 1 of 3 SSU channels.		
9	ε	Command verification without commands being initiated.	Attributed to spurious ground signals in the frequency band of the command receiver.	No mission effect.		Receiver operates in a band that carries TV and amateur radio traffic.
10	ε	Incorrect constant in on-board software caused a 5° yaw error.	Unknown.	Negligible	Software corrected.	
11	ε	TCE #2-#16 turned off erroneously at turn-on of CPU #1.	Unknown.	No effect, TCE'S commanded back on.		
12	ε	SEM TED proton counters output higher than expected at first turn-on.	Unknown.	No effect, operation is normal in bias mode.		
13	ε	GEODAT program not running in back-up CPU.	Unknown.	Negligible; started via command.		
14	160	Incorrect error factor gyro bias constants.	Software problem.	Small, correct calibration constants were loaded.		
15	260	Day/night flag in CPU telemetry appeared 1.5 minutes late.	Software problem.	Negligible, on-board software corrected.		
16	270*	CPU #1 telemetry lost sync after dump of stored command table.	Software problem.	Negligible; was disabled and reenabled to regain sync.	Software change mode for subsequent spacecraft.	
17	380	Eclipse flag did not come on after eclipse.	Software problem.	Negligible; on-board software corrected.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		TIROS-N				
18	480	MSU channel 2 space temperature calibration point drift.	Unknown.	No impact on data quality.		Drift stabilized at acceptable point.
19	1,200	S-band transmitter #3 power output dropped from 9 watts to 4 watts.	Unknown.	Small.		Transmitter continued to be used but link threshold is marginal at elevations below 20°.
20	1,650	Battery currents went to c/300 instead of c/60 when power sub-system went into trickle charge mode.	Unknown.	No impact.		
21	1,700+	High bit rate errors on DTR #2A and 2B.	Unknown.	Small, error rate reduced by running the tape transports from end to end several times.		
22	1,990+	Back-up computer malfunction due to intermittent "stuck" bit in ROM address register position 5.	No effect, use CPU #1.		High input gate leakage is the suspect failure mechanism which was seen on NOAA-A.	
23	2,060	AV[illegible] space and back-scan values changed abruptly over a period of 25 seconds.	Due to moon in field in view.	No effect.		
24	2,110	All ESA detectors show a rapid change at sun interference in quads 2 and 4.	Unknown.	No effect; corrected via software thres-hold reset.		
25	2,130	HIRS space view values changed for 3 cycles then returned to normal.	Due to moon in field of view.	No effect.		
26	2,250+	SSU lost sync in auto calibrate mode.	Due to noise spike on 1 KHz clock.	No effect on data gathering.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
		TIROS-N				
27	4,1[illegible]	Failure of temperature sensor.	Unknown.	Loss of house-keeping telemetry point.		
28	7,130	Commanding failed to activate SEMS TED proton output.	Unknown.	No effect.		
29	7,320	Slight spacecraft attitude shift when sun-moon flag set for 2 ESA quads.	Due to minor algorithm error; algorithm assumes spherical instead of ellipsoidal earth.	Not serious.		
30	9,280	Erratic behavior of the yaw gyro caused earth sensor quadrant loss indication and an abnormal shift to yaw gyro compassing mode.	Unknown.	Negligible.	Backup skewed gyro commanded to replace yaw gyro.	
31	11,130	CPU #1 failed.	Possibly due to failure in CPU control logic.	Small, CPU #2 had to be used despite erratic behavior.		Spacecraft went into tumbling and control restored 5 days later.
32	11,520	AVHRR channel 3 change in calibration.	Attributed to reduction of optics contamination due to direct exposure to sunlight during tumbling (see anomaly #31).	Negligible.		
33	12,600	Thruster valve #9 exhibited high temperature excursions reaching peak of 44°C.	Suspect that a heater which is bonded to a thermistor lifted.	Negligible, temperature did not increase enough to cause any problem.		
34	14,780	Temperature runaway of battery pack 2A after several days of erratic behavior.	Due to a shorted cell caused by manfacturing techniques.	Negligible, remaining battery packs sufficient to carry spacecraft load.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		TIROS-N				
35	16,270	IMU power supply failed.	Unknown.	Small		Redundant unit selected but in the interim the CDU selected improper attitude control modes and the SSU lost sync.
36	16,920	Battery 1A temperature increase.	Attributed to "soft" short caused by manufacturing techniques.	Small, battery stabilized after special charge regime.		
37	17,230⁺	DTR 3A/3B intermittent high bit error rates.	Possibly due to intermittent in recorder data handling circuitry.	Negligible, did not effect data collection.		
38	17,420	HIRS patch power telemetry indicates low values; intermittent.	Attributed to noise.	No effect.		
39	17,900	Pitch gyro bias shift.	Degradation due to aging.	No impact on mission.		
40	17,970	AVHRR; loss of output.	Thought due to blown fuse caused by a shorted filter capacitor on the +28V input power line.	Loss of instrument.		
41	18,000⁺	Erratic behavior of pitch gyro.	Unknown.	Caused increasing yaw updates.		Since yaw gyro also marginal spacecraft switched to yaw gyro compass mode; could mean up to 1° error in attitude performance.
42	19,030	ESA change in detector output for quadrant 1.	Unknown.	Small, causes 0.35° pointing error perturbation in roll and pitch during periods of moon interference.		
43	20,800	Backup IMU power supply failed; primary already failed-see anomaly #36.	Unknown.	End of mission.	Spacecraft went into tumbling, control could not be regained; battery voltage degraded and spacecraft could not be contacted.	

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SEASAT				
1	ε	SAR antenna panel backside temperature sensor went from -47.5°F to +160.8°F while front side sensor stayed between 54°F to 44°F.	Due to overlaid data from another temperature sensor.	Negligible, software tables corrected.		
2	ε	Radar altimeter showed 2 temperature points significantly warmer than expected.	Possibly due to gap between corners and shield, optical properties of corners.	Negligible.		
3	240	Scan motor temperature from analog data 5° higher than same temperature point from digital data.	Possibly due to calibration error.	Negligible.		Digital data used from the platinum resistance thermometer which is the more reliable sensor.
4	240	Altimeter thermostat cycled rapidly.	Attributed to transferring of material from thermostat points thus altering the gap.	Negligible, work-around developed.		
5	265	L-band power amp power monitor reading dropped abruptly from 773 watts to 647 watts.	Due to some unexplained change in the power monitor.	Negligible, actual transmitted power was normal.		
6	290	SAR transmitter driver current out of specification.	Due to pre-launch error in establishing high limit.	Negligible; not a problem with radar.		
7	290	SAR temperature monitor was discovered to be faulty.	Unknown.	Loss of telemetry point.		Was found to have failed before launch.
8	290	SASS input voltage monitor low limit setting does not reflect the IR drop in cable and is thus below the lower limit of the interface voltage required for operation.	Unknown.	Small.	SASS input voltage monitor limit was revised to 20.6v in software.	
9	315	21 GHz electrical temperature monitor failed.	Unknown.	Loss of telemetry point.		Item reported as failed pre-launch, then worked well for over 300 hours, then failed again.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SEASAT				
10	505	Excessive radar altimeter baseplate temperature.	Unknown.	Negligible.		Radar altimeter commanded off for 9 days.
11	935	Glitch in altimeter current.	Unknown.	Negligible.		
12	1,030	Large error in front scanner quadrant.	Caused by sun interference in right scanner of the horizon scanner.	Small	Work-arounds developed to disconnect roll-error signals during predicted interference period.	Not known why interference not also exhibited in rear quadrant.
13	1,080	VIRR detector temperature approached upper limit of 95°F (was 94.3°F).	Unknown.	Negligible.		VIRR was turned off for cooling and special monitoring implemented to turn it off before it reached 100°F.
14	1,510	VIRR scan motor stopped rotating.	Unknown.	Small.		Started operating again but failed permanently again 12 days later.
15	1,515	Altimeter low voltage monitor shut down the altimeter transmitter.	Due to low voltage on unregulated bus.	Negligible, loss of 9 days of altimeter use.		
16	1,560	Altimeter signal processor temperature monitor climbed 16°C in 7 minutes when the heater bus was turned on.	Due to temperature monitor being mounted too close to heaters and both heaters on.	No effect.		
17	1,660	Ground station unable to hold solid lock on spacecraft receiver.	Suspected frequency shift in spacecraft downlink.	Negligible.		
18	1,895	High data rate recorder low order channels bad; parity errors.	Unknown.	Unknown.		SEASAT failed before anomaly investigated.
19	1,970	VIRR no voltage circuit was found in disabled state after a command sequence to start the VIRR scan motor.	Due to sneak circuit between affected disable command and the VIRR shutdown command.	Small, work-arounds developed.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		SEASAT				
20	2,280	Missing data in SMMR scan data; several occurrences.	Due to loss of data loads, one occurrence due to bit error.	No impact.		
21	2,520	Short circuit in solar array slip ring assy.	Design of slip ring assy prone to shorting.	Loss of mission: current drain reduced power levels and drained batteries; S-band contact with spacecraft lost.		Similar problems on other Agenas.
22	-	Pitch and roll excursions.	Due to cold clouds.	Negligible.		
		SME				
1	c	1.27 micron spectrometer ACLDV read high limit error toggles in and out.	The unit possibly breaks limit when looking at bright earth.	Negligible.		
2	c	Observatory module temperature exceeds specifications at low end (ie, too cold).	Unknown.	Caused intermittent incorrect operation in several instruments.		Impact of low temperature on instruments had been seen prelaunch.
3	c	Tape recorder A did not respond to playback command and on next pass did not indicate ready.	Unknown.	Negligible, recorder operated normally after it was left in playback at the end of the pass and temperatures reached 38°C.		Symptoms seen in prelaunch tests.
4	c	Observatory Module spatial reference status and configuration changes.	Unknown.	Negligible.		
5	340	Battery #1 cell fail alert occurred.	Unknown.	Negligible.	Different voltage/ temperature regime commanded.	
6	385	1.27 micron spectrometer ACLDV out of limits.	Unknown.	Negligible.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VIKING ORBITER 1				
1	15,575	Two to 5 db degradation in either the RF system or command detector unit.	Unknown.	Negligible.		
2	19,680	Gas leak in roll axis.	Due to a strong and variable gravity gradient torque near periapsis.	Negligible.		
		VIKING LANDER 1				
1	c	Telemetry indication of reduction in internal pressure within RTG-1.	Due to leakage of gases into the 4cc pressure transducer reference cavity.	Negligible, did not degrade RTG performance.		Suspected prior to launch based on prelaunch pressure data.
2	c	De-orbit feedline heater thermostat duty cycle changed.	Due to 1 of 2 series thermostats failing closed.	Negligible, redundant thermostat used.		
3	c	Battery temperatures predicted to increase by 15° but increased by 40°.	Temperature predictive model not based on flight battery data (based on pre-production prototype batteries) and was in error.	Negligible, temperatures stabilized ok.		
4	c	GCMS ion pump current turn-on transient.	Unknown.	Small.	Pump off times limited to less than 5 minutes, established rule to not turn-off pump under load; conducted ion pump characterization tests.	
5	2,000	Valve drive amplifier power 60% greater than recorded in prelaunch checkouts.	Due to a combination of increased viscous friction of the throttle valve lubricant, and unbalanced pressure differential across the throttle valve bellows under cruise.	No effect.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VIKING LANDER 1				
6	8,000	UHF transmitter operated in 1 watt mode instead of the planned 30 watt mode.	Possibly due to a short in a 100 ohm resistor or a sensitive IC chip causing coupling between logic gates or an intermittent short.	Negligible.	Mode control logic line drivers "on" continuously for pertinent modes.	
7	8,000	All amplitude data in the seismometer data stream went to zero.	Possibly due to system transients.	Negligible.	Self correct by cycling seismometer.	
8	8,060	Surface Sampler (SSCA) latch pin jammed.	Due to control sequence containing an insufficient boom command to free the boom restraint latch pin.	Negligible.	Corrective commands transmitted.	
9	8,230	Variations in GCMS ion pump current from day to day.	Due to arcing/corona.	Resulted in operations with a degrading high voltage source.	Cycle ion pump off and on for 1 minute during atmospheric analysis experiments.	
10	8,600	GCMS "level full" signal not received.	Unknown.	Negligible.	Vibrate GCMS shuttle while metering; "level full" signal subsequently received.	
11	9,720*	Surface Sampler "no-good" during excavations on several occasions.	Due to short from a small metallic particle in cable insulation or partial delamination of the cable insulation.	Negligible.		
12	12,500	Receiver #2 did not lock-up during downlinks for 1½ hours.	Attributed to loss of receiver sensitivity or spurious lock on some other signal or RFI.	Negligible.	Used different uplink sweep but still recurred.	
13	13,950	Double execution relay link anomaly during orbiter playback of lander data.	Unknown.	Negligible.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VIKING LANDER 1				
14	14,280	Biology chromatograms had no peaks.	Due to soil splatter which may have prevented sealing of the test cell, or cell drain valve may have failed open or valves used to sample head space gas may have failed.	No effect, since instrument had already run out of helium.		
15	17,000	Unexpected 6db decrease in Receiver #2 AGC.	May be manifestation of anomaly #12.	Negligible but intermittent problem.	Receiver not used when temperature exceeded 67°F.	
16	-	Open circuit in wind sensor #2.	Unknown.	Can still acquire wind data but accuracy degraded.		
17	-	Telemetry DAPU block coder clock changed phase by 180°.	Unknown.	Negligible.	Changed ground operations software.	Caused drop in SNR and occasional loss of telemetry signal.
		VIKING ORBITER 2				
1	17,480	During planned switch from Processor B to A, uncommanded switch to low-gain antenna and single subcarrier mode occurred.	Due to timing offset between Processor A and B.	Small effect.	Corrected via commands.	Caused a spacecraft emergency.
2	18,800	Leak in yaw axis attitude control jet.	Unknown.	Negligible.	Commanded yaw turn to clear jet.	
3	21,170	Major leak developed in roll axis; continued for 2 days, then intermittently.	Unknown.	Negligible.		Lost 2 pounds of gas; spacecraft commanded to roll-drift mode to conserve the little remaining gas.
4	21,170*	Leak developed in redundant RCS.	Unknown.	This anomaly and anomaly #3 caused depletion of control gas and spacecraft shut down.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VIKING LANDER 2				
1	2,300	Spacecraft disturbance.	Possibly due to base ring latch mechanism obstructing the bioshield cap ring during separation.	No impact.		
2	2,300	X and R gyro bias erratic and did not stabilize.	Due to coupling into Canopus tracker and lack of roll filtering in software.	No impact.		
3	2,300	Command detector in phase integrator noisy when off.	Due to "off" impedance of the resistance type transducer being in excess of 130,000 ohms.	No impact.		Noise had been seen in pre-launch tests.
4	2,300	Terminal descent valve driver amplifier current 20% higher than seen in tests.	Unknown.	No impact.		
5	2,300	Meteorology ambient temperature sensor noise increased such that the difference between the reference and ambient temperature was 20° relative to 10° expected maximum.	Unknown.	No impact; continued throughout.		Pre-launch value was 16.5°.
6	3,450	GCMS LPA carriage strobe light failure.	Probably due to electrical problem.	Negligible	Recovery plan developed but not clear what it did or whether it was needed.	
7	8,590	Terminal descent landing radar experienced 2 periods of false lock.	Due to low frequency noise or vibration.	Negligible, 3 other channels available.		
8	8,690	Loss of bits during tape recorder playback on Track 4, reverse direction.	Possibly due to timing relationship during record/playback.	No impact.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VIKING LANDER 2				
9	10,150	Approximately 20 minutes of GCMS organic analysis data missing from tape on playback.	Caused by fast noise glitch.	Small; slight loss of data but subsequent operation normal.		Tape recorder apparently turned-off early due to GCMS "data ready" signal going inactive early.
10	11,930	Met instrument data missing from relayed data transmission.	Due to timing conflict.	Small; slight loss of data.	Corrected via software.	
11	13,630	SSCA boom stopped azimuth travel at about 39°.	Unknown.	Small; boom achieved commanded positions in subsequent operations.		Not investigated since surface sampling terminated at about this time.
12	18,190	TWTA #2 failed.	Probably due to a failure in the low voltage supply/voltage regulator of the TWTA.	Caused loss of Lander II downlink; Lander II had to be operated via a relay link with an orbiter.		Similar occurence happened on Viking Lander I a year before.
13	39,550	Computer failed.	Unknown.	Operations with Lander II were terminated.		
		VOYAGER 1				
1	c	Unexpected on-board command to switch from primary pitch and yaw thrusters to redundant thruster branch when magnetometer boom was extending.	Possibly due to extending boom causing motion in spacecraft and on-board computer switched thrusters to correct motion.	No effect.	Reconfigured via ground command.	
2	140	Unexpected on-board command to switch from primary roll thrusters to redundant thruster branch during first roll turn of spacecraft.	Possibly due to incompatibility of the turn rate to position gain and incremental rate dumping with the magnetometer/science boom higher order structural frequencies which causes the number of roll pulses generated to exceed the pulse count limit.	No effect.	On-board software modified.	Occurred three times on Voyager I and several times on Voyager II.

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 1				
3	190	Thrust velocity ΔV 20% less than expected.	Due to thruster exhaust plumes impinging on portions of the spacecraft.	Small, required more hydrazine use than planned for all maneuvers.		Maneuver planning implemented to conserve hydrazine.
4	2,400	The 12th bit of the FDS "A" memory failed high.	Unknown.	Negligible; on-board software modified to preclude use of failed. memory location.		Found when both the wide angle and narrow angle televisions did not respond to filter-wheel stepping anomalies.
5	4,100	Commanded scan platform azimuth slew was not successful.	Possibly due to debris (possibly from assembly at JPL) in azimuth gears and later crushed by gears.	Negligible, scan platform became unstuck and operation favorable.		
6	4,460	S-band high gain antenna driver solid state amplifier exhibited degraded RF power output and decreased input current in the 20 watt high power mode.	Attributed to early wearout of 1 or more MSC 3005 transistors in each of the amplifiers.	Small.	Operational procedure instigated to use low power mode whenever possible and minimize high power mode.	
7	10,920	Commands generated by CCS processor A occurred 48 seconds early.	Believed caused by extra counts picked up by a ripple counter due to a time phasing problem.	Small.	Processor A clock was reset from the ground to eliminate the 48 second offset.	
8	11,660	Gyro A pitch axis showed abnormal drift rate and drift rate-rate of change.	Attributed to low capture loop gain.	Small.	Gyro conditioning tests instituted at six month intervals.	
9	12,770	Photo polarimeter analyzer wheel sticking.	Unknown.	Negligible.		Was commanded to and left in the clear position for the Jupiter encounter.
10	13,100	FDS clock lost 8 seconds.	Due to 40 spurious power-on reset signals which were probably caused by Jovian radiation.	Negligible.	Software modified on Voyager II.	

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 1				
11	19,250	Star tracker locked on Alpha Centauri instead of Canopus after a series of turns.	Unknown.	Created a spacecraft emergency.	Spacecraft was commanded through a side lobe to switch to the low gain antenna and contact was thus re-established; re-acquisition commands were then transmitted.	Contact was lost since antenna was not pointing towards earth.
12	25,560	X-band feed temperature transducer intermittently produces saturated readings.	Possibly due to partially open circuit associated with the series or parallel padding resistors.	Not serious; loss of telemetry point.		
13	25,730	Scan platform executed elevation slew commands properly but then crept out of commanded position.	Probably due to cable wind-up which can apply enough torque to pull the scan platform.	Negligible.	Uplinked software to store slew commands and re-execute them every 48 seconds to reposition platform if creep has occurred.	
14	26,060	Star tracker #2 could not be commanded into cone angle settings 3,4 or 5.	Possibly due to transistor leakage caused by 2 or more Delrin insulating sleeves decomposing due to high intensity radiation.	Some loss of sensitivity.	Software modified to permit operational work-around.	
15	27,000	Plasma instrument stopped transmitting usable data.	Possibly due to internal short or bad connection.	Negligible		Reactivated, but problem recurred three months later.
16	30,960	Photopolarimeter filter wheel stopped.	Possibly due to 1 of 4 transistors in a transistor bridge in the filter wheel stepper motor circuit shorting out.	Instrument degraded to some extent.		
17	35,780	Bit 4 in all 8K words of FDS memory B stays high.	Most probable cause is that a CD 4049 integrated circuit inverter failed high or its input shorted to low.	FDS memory B not usable; operations limited to FDS memory A.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 1				
18	-	Crystalization and hardening of the motor dampers on the Michelson motor in the infrared spectrometer and radiometer.	Unknown.	Negligible.	The flash off heater was used to raise the temperature and halt the degradation.	The heater was originally installed only to evaporate condensation during launch.
		VOYAGER 2				
1	ε	The microswitch on the folding strut did not provide the signal which indicates full deployment of the science boom.	Probable cause is debris in the folding strut hinge or insufficient drive in the folding strut.	Negligible.		Science boom deployed to within 0.2° of latching but did not latch; later it was found to be within 0.06° of the correct position.
2	ε	Following the Release PTG Boom command, no indication was received that the Pyro Amps B had activated.	Some evidence that a transistor in the output switching portion of the pyro switching unit failed.	Negligible, used redundant unit.		Not known whether Pyro Amps B did not activate or whether the telemetry indication was wrong.
3	ε	Following the spacecraft launch vehicle separation command, an indication was received that both pyro "superzip" strands A and B were activated.	Due to faulty telemetry caused by combination of an unbalanced grounding design in the pyro switching unit and that the superzip squibs short to ground during firing.	No effect.		
4	ε	Short pitch and yaw disturbances.	Due to outgassing.	Not serious.		
5	ε	Large attitude excursions in pitch and yaw.	Star tracker low gate setting upset due to a flurry of bright particles.	Negligible.	Star tracker softwere modified.	
6	ε	Sun search required 3½ hours instead of predicted five minutes.	On-board processor had improperly positioned the spacecraft for the search due to processor switching relationships.	No mission effect.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 2				
7	ε	The on-board computer unexpectedly switched from the primary to back-up gyros.	First occurrence due to the gyros inability to keep up with booster motion and the second due to high vibration.	No mission effect.		Switch occurred because the computer "thought" the gyros had failed when their data did not match.
8	ε	First attempt to eject science cover unsuccessful.	On-board computer did not give the command because the second computer was switching memory banks at the same time and the software inhibits any maneuver when such switching occurs.	Negligible, second attempt successful.		
9	120	Spacecraft went into gyrations.	Probably not a hardware problem.	Negligible.		May be related to anomaly #5.
10	130	Thrust velocity ΔV less than expected.	Due to thruster exhaust plume impingement on portions of the spacecraft.	Small, required more hydrazine use than planned for all maneuvers.		Maneuver planning implemented to conserve hydrazine.
11	240	Unexpected on-board command to switch from primary to backup thrusters.	Possibly due to extending boom or incompatibility of the turn rate to position gain.	No effect.	On-board software modified.	Occurred five times.
12	265	Photopolarimeter analyzer wheel stuck in position 2.	Probably failed IC in either a multiplexer or the motor step logic.	Degraded instrument to some extent.		
13	815	Incorrect telemetry data from FDS engineering data commutator tree switch #3.	Most likely cause is a leaky IC at one of the two input multiplexers.	15 of 243 engineering telemetry points were lost.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 2				
14	1,800	Low energy charged particle instrument motor winding drew too much current and overheated the instrument.	Due to one of the motor winding logic flip-flops changing states, possibly due to a transient from x-band turn-on.	Small impact. The instrument is fully functional in slow scanning mode, but accelerated stepping mode is no longer possible because the lowered resistance would allow excessive current flow.		
15	1,940	S-band high gain antenna driver solid state amplifier exhibited degraded RF power output and increased current input in the 20 watt high power mode.	Attributed to early wearout of 1 or more MSC 3005 transistors in each of the amplifiers.	Small.	Operational procedures instigated to use low power mode whenever possible and minimize high power mode.	
16	2,420	X-band TWTA high gain antenna drive telemetry monitor erratic when receiver goes in or out of lock.	Due to a design problem that was left uncorrected due to schedule and cost consideration.	Not significant.		
17	2,570	Infrared spectrometer misalignment and increase in instrument NER.	Due to crystallization of the silicon rubber of the motor damper and beam splitter mounts.	Negligible.	Flash-off heater used to provide warming cycles for the instrument.	
18	5,500	RFS #1 failed.	Possibly due to a problem in the receiver's power supply.	Loss of receiver #1; backup unit #2 available but had an anomaly (#19) and Radio Astronomy Experiment could be used as a receiver if necessary.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 2				
19	6,190	RFS Receiver #2 lost its capability for adjusting for the effects of the Earth's rotation on the uplink signal.	Due to failed capacitor in receiver's tracking loop.	Negligible.	Uplink frequencies adjusted to match what the receiver "thought" they should be.	
20	15,700	Heating of 1 side of the spacecraft bus when the spacecraft maneuvered off the sun line or when power consumption changed.	Unknown.	Small.	Contingency plans developed.	
21	16,500	During Jupiter encounter, radiation built-up a charge on the spacecraft which dissipated through electro-static discharge.	Unknown.	The command receiver, wide angle television, photopolarimeter, and Cosmic Ray Experiment were damaged by Jovian radiation and electrostatic discharge caused frame start resets in the wide angle television.		
22	16,660	HET 2 Telescope guard circuitry hung-up in "high" state and causes loss of detector counts in channels 12,13,14, and 15.	Due to failure in the guard ECL circuit; either 1 of 3 transistors or a shorted capacitor.	No effect since instrument commanded to lower gain state.		
23	16,850	Photopolarimeter filter wheel skips every other position.	Possibly due to a failed part; probably related to anomaly #21.	Negligible, information still usable.		
24	16,850	Cosmic Ray Experiment probably lost a commutator.	Possibly due to a weak part failure; probably related to anomaly #21.	Redundant unit available.		
25	32,830	Loss of the 7th LSB in the upper 256 words of FDS Memory B.	Due to failure of a 1x 256 RAM, CD 4061A (a hybrid integrated circuit).	Small, FDS operations limited to Memory A.		

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		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		VOYAGER 2				
26	35,180	Scan platform azimuth actuator stuck at 260° azimuth and 20° elevation.	Possibly related to wear of gears and a lubricant problem.	Significant, scan platform stuck while the spacecraft was behind Saturn so this data lost.	Platform unjammed by using motor at higher speed.	Eventually elevation motion normal but azimuth motion restricted.
27	-	Spacecraft attitude changes.	Due to tape recorder motion.	Negligible.	Corrected via software.	Caused smearing of images.

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APPENDIX B-2

ANOMALY CLASSIFICATIONS
THE STANDARD APPROACH

ANOMALOUS INCIDENT CLASSIFICATION CODES, STANDARD APPROACH

I. Mission Subset

U. Unsuccessful Launch

S. Spacecraft with No Anomalies Reported

Spacecraft with Anomalies Reported

II. Mission Term

L. Long Term

S. Short Term

III. Mission Phase

L. Launch and Acquisition

O. Orbital (Steady-State)

Q. Unknown

IV. Mission Effect

1. Negligible

2. Non-Negligible but Small

3. 1/3 to 2/3 Mission Loss

4. 2/3 to Nearly Total Mission Loss

5. Essentially Total Mission Loss

U. Unknown

V. Spacecraft Subsystem

a. Timing, Control and Command

b. Telemetry and Data Handling

c. Power Supply

d. Attitude Control and Stabilization

d† Propulsion

e. Environmental Control

f. Structure

g. Payload (Experimental and Scientific)

h. Unknown

VI. A. Incident Type

E. Electrical

M. Mechanical

O. Other

U. Unknown

VI. B. Incident Type

C. Catastrophic Part Failure

O. Other Part-Related Incident

N. Non-Part-Related Incident

U. Unknown

VII. Incident Cause

A. Assignable

N. Non-Assignable

U. Unknown

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					AE-5				
1		L	O	2	a	E	N	A	4
2		L	L	1	d*	E	N	A	2
3		L	O	1	c	E	N	U	3
4		L	O	1	g	E	N	A	1
5		L	O	2	g	E	U	U	1
6		L	O	1	d	E	U	U	2
7		L	O	1	c	E	N	A	3
					AEM-1 (HCCM)				
1		L	O	1	g	U	U	U	1
2		L	O	1	a	E	N	A	5
3		L	O	1	a	E	N	A	3
4		L	O	1	b	E	N	A	3
5		L	O	1	b	E	N	A	5
6		L	O	1	d	E	N	A	1
7		L	O	1	b	E	N	A	1
8		L	O	1	a	E	N	A	4
9		L	O	3	c	E	O	A	2
10		L	O	1	g	O	N	A	1
11		L	O	3	a	E	N	A	5
12		L	O	1	a	E	N	A	5

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					AEM-1 (HCCM)				
13		L	O	1	g	O	U	U	1
					AEM-2 (SAGE)				
1		L	L	1	f	M	N	A	2
2		L	O	2	e	O	N	A	1
3		L	O	1	d	O	N	A	1
4		L	O	1	a	E	N	A	5
5		L	O	1	b	E	N	A	5
6		L	O	4	c	E	O	A	2
7		L	O	1	d	E	U	U	1
8		L	O	1	c	E	U	U	3
9		L	O	1	d	E	N	U	2
10		L	O	1	d	E	N	A	1
					ATS-1				
1		L	O	1	d	U	U	U	2
2		L	O	1	a	E	U	U	3
3		L	O	1	d	E	U	U	3
4		L	O	3	c	E	U	U	3
5		L	O	3	c	E	U	U	3
					ATS-3				
1		L	O	2	a	U	U	U	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					ATS-3				
2		L	O	2	d	U	U	U	2
3		L	O	2	c	E	U	U	3
4		L	O	3	c	E	U	U	3
					ATS-5				
1		L	O	3	a	E	N	A	1
2		L	O	2	c	O	N	N	3
3		L	O	1	a	E	U	U	1
4		L	O	1	g	M	N	A	1
5		L	O	1	c	E	O	N	3
6		L	O	1	c	E	O	N	3
7		L	O	1	b	E	N	A	1
8		L	O	1	c	E	U	U	3
9		L	O	2	c	E	N	A	3
					ATS-6				
1		L	O	1	c	E	U	U	3
2		L	O	1	d*	M	N	A	2
3		L	O	1	d*	M	N	A	2
4		L	O	1	d*	M	N	A	2
5		L	O	1	d*	M	N	A	2
6		L	O	2	g	E	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					ATS-6				
7		L	O	1	d*	M	N	A	2
8		L	O	1	a	E	U	U	1
9		L	O	1	d*	M	N	A	2
10		L	O	1	d*	M	N	A	2
11		L	O	1	d*	M	N	A	2
12		L	O	1	d*	M	N	A	2
13		L	O	1	d*	M	N	A	2
14		L	O	1	d*	M	N	A	2
15		L	O	1	d*	M	N	A	2
16		L	O	1	d*	M	N	A	2
17		L	O	1	b	E	N	A	5
18		L	O	2	b	E	N	A	5
19		L	O	1	d*	M	N	A	2
20		L	O	1	d*	M	N	A	1
21		L	O	1	d	E	U	U	1
22		L	O	1	d	E	N	A	1
23		L	O	1	d	O	U	U	1
24		L	O	1	e	O	U	U	1
25		L	O	1	e	O	N	U	1
26		L	O	1	e	O	N	A	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					DE-1				
1		L	O	1	a	E	N	A	3
2		L	O	1	b	O	N	A	3
3		L	O	1	b	E	N	A	5
4		L	O	1	b	U	U	U	1
5		L	O	1	b	U	U	U	1
6		L	O	1	b	E	N	A	5
7		L	O	1	g	E	N	U	1
8		L	O	1	a	E	N	U	2
9		L	O	1	a	E	N	U	1
10		L	O	1	a	E	N	U	1
11		L	O	2	g	E	O	A	1
12		L	O	1	e	E	C	N	1
13		L	O	1	a	E	N	U	5
14		L	O	2	a	E	N	A	1
					DE-2				
1		L	L	2	g	E	N	U	1
2		L	O	2	c	E	N	U	3
3		L	O	1	g	E	N	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					DE-2				
4		L	O	2	b	E	U	U	5
5		L	O	1	d	E	U	U	1
6		L	O	2	d	E	N	U	2
7		L	O	1	b	E	N	A	5
8		L	O	2	a	E	U	U	3
9		L	O	2	g	E	U	U	1
10		L	O	1	a	E	N	U	5
					GOES-1				
1		L	O	1	b	E	U	U	7
2		L	O	1	g	E	U	U	1
3		L	O	2	g	E	U	U	1
4		L	O	1	a	E	U	U	1
5		L	O	1	c	E	C	N	1
					GOES-2				
1		L	O	2	g	E	C	N	1
2		L	O	1	g	E	U	U	1
3		L	O	3	g	E	U	U	1
4		L	O	2	g	E	C	N	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					GOES-2										GOES-4				
5		L	O	1	b	E	U	U	5	4		L	L	3	g	E	N	A	1
6		L	O	1	b	E	U	U	1	5		L	L	1	g	E	U	U	1
					GOES-3					6		L	L	1	a	E	U	U	1
1		L	O	2	g	E	U	U	1	7		L	L	1	b	E	U	A	5
2		L	O	1	d	E	N	U	5	8		L	L	1	g	E	N	A	1
3		L	O	3	g	O	N	A	1	9		L	L	1	b	O	N	A	5
4		L	O	2	g	U	U	U	1	10		L	L	1	g	E	U	U	1
5		L	O	1	g	E	U	U	1	11		L	L	1	d	O	N	A	2
6		L	O	2	g	E	U	U	1	12		L	O	1	b	E	N	A	5
7		L	O	1	g	E	U	U	1	13		L	O	3	g	E	C	N	1
8		L	O	1	g	E	N	U	1	14		L	O	1	d	O	N	A	2
9		L	O	4	g	E	O	A	1	15		L	O	3	g	O	N	A	1
10		L	O	1	g	E	C	N	1	16		L	O	2	g	O	N	A	1
11		L	O	1	c	E	C	N	1	17		L	O	1	b	E	N	A	5
					GOES-4					18		L	O	1	b	E	N	N	5
1		L	L	1	f	O	N	A	1	19		L	O	1	b	E	O	N	4
2		L	L	2	d*	O	N	A	2	20		L	O	1	b	E	O	A	5
3		L	L	2	c	E	U	U	3	21		L	O	1	b	E	U	U	5

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
GOES-4									
22		L	O	1	b	O	N	A	5
23		L	O	1	b	E	U	U	5
24		L	O	3	b	M	U	U	5
25		L	O	3	c	E	N	N	3
26		L	O	1	d	M	N	N	2
27		L	O	1	c	E	U	U	5
28		L	O	1	b	E	U	U	5
29		L	O	1	c	E	U	U	3
30		L	O	1	b	E	U	U	5
31		L	O	1	g	M	U	U	1
32		L	O	3	b	O	U	U	1
GOES-5									
1		L	L	2	g	O	N	A	1
2		L	O	1	b	E	O	A	5
3		L	O	2	g	O	N	A	1
4		L	O	2	b	E	U	U	5
5		L	O	2	d	E	U	U	2
6		L	O	2	g	M	N	A	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
GOES-5									
7		L	O	3	g	E	U	U	1
8		L	O	1	b	E	U	U	5
9		L	O	3	c	E	N	N	3
10		L	O	1	c	E	U	U	3
11		L	O	1	g	E	U	U	1
12		L	O	1	g	M	U	U	1
13		L	O	1	b	E	U	U	5
14		L	O	1	b	O	U	U	5
15		L	O	1	c	E	U	U	3
16		L	O	1	c	E	U	U	3
17		L	O	1	d	M	N	N	2
IMP-8									
1		L	O	1	g	U	U	U	1
ISEE-1									
1		L	L	2	g	E	N	A	1
2		L	O	1	g	E	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					ISEE-1				
3		L	O	2	g	O	N	A	1
4		L	O	2	g	E	U	U	1
5		L	O	2	g	E	N	U	1
6		L	O	1	e	O	U	U	1
7		L	O	1	g	E	U	U	1
8		L	O	1	g	E	U	U	1
9		L	O	1	d	E	N	A	1
10		L	O	1	g	E	N	A	1
11		L	O	2	g	E	N	A	1
12		L	O	3	c	E	N	A	2
					ISEE-2				
1		L	O	1	c	E	U	U	3
2		L	O	1	g	E	U	U	1
3		L	O	1	g	O	N	A	1
					ISEE-3				
1		L	O	3	g	E	U	U	1
2		L	O	3	g	O	U	U	1
3		L	O	2	g	E	N	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					ISEE-3				
4		L	O	2	g	E	U	U	2
5		L	O	1	d*	O	N	A	1
6		L	O	1	g	U	U	U	1
7		L	O	1	c	E	N	A	3
					IUE				
1		L	O	1	d	E	C	N	2
2		L	O	1	b	O	N	A	4
3		L	O	1	e	O	N	A	1
4		L	O	1	g	O	N	A	1
5		L	O	1	g	E	U	U	1
6		L	O	1	d	O	U	U	1
7		L	O	1	g	E	O	A	1
8		L	O	1	b	E	N	A	5
9		L	O	1	b	O	O	N	5
10		L	O	1	b	O	U	U	4
11		L	O	1	d	M	O	N	1
12		L	O	1	g	O	N	A	1
13		L	O	1	g	E	O	N	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					IUE				
14		L	O	1	g	O	N	A	1
15		L	O	1	a	E	N	A	1
16		L	O	1	b	E	N	N	4
17		L	O	1	e	E	U	U	1
18		L	O	1	g	O	N	N	1
19		L	O	1	d	O	O	N	1
20		L	O	1	d	O	O	N	1
21		L	O	1	b	E	U	U	5
22		L	O	2	d	E	N	A	1
23		L	O	1	d	O	U	U	1
24		L	O	1	d	E	U	U	1
					LANDSAT-2				
1		L	O	1	d	O	N	A	1
2		L	O	1	c	E	U	U	3
3		L	O	1	c	E	N	A	3
4		L	O	1	a	E	U	U	1
5		L	O	1	b	E	U	U	4
6		L	O	1	d	E	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					LANDSAT-2				
7		L	O	1	b	E	U	U	4
8		L	O	4	d	O	N	A	1
9		L	O	3	b	E	U	U	4
10		L	O	2	b	E	U	U	4
11		L	O	1	b	E	U	U	5
12		L	O	1	c	E	U	U	3
13		L	O	1	d	O	N	A	2
14		L	O	1	a	E	U	U	2
15		L	O	1	d	E	U	U	1
16		L	O	1	c	E	U	U	5
					LANDSAT-3				
1		L	C	1	d	M	N	A	1
2		L	L	1	d	E	U	U	1
3		L	O	1	a	O	U	U	3
4		L	O	1	g	E	U	U	1
5		L	O	1	a	O	U	U	3
6		L	O	1	g	E	U	U	1
7		L	O	1	a	O	N	N	2

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					LANDSAT-3				
8		L	O	3	g	E	N	A	1
9		L	O	1	b	E	U	U	4
10		L	O	1	b	E	O	N	4
11		L	O	1	b	E	N	A	4
12		L	O	3	g	E	U	U	1
13		L	O	1	c	E	U	U	1
14		L	O	1	b	E	U	U	5
15		L	O	1	b	E	N	N	4
16		L	O	1	b	E	N	A	4
17		L	O	1	c	O	N	A	3
18		L	O	1	g	E	N	A	1
19		L	O	1	d	E	N	A	1
20		L	O	1	d	E	U	U	1
21		L	O	3	b	E	U	U	4
22		L	O	2	d	O	N	A	1
23		L	O	1	b	E	N	N	5
24		L	O	1	a	O	N	A	3
25		L	O	1	a	O	O	A	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					LANDSAT-3				
26		L	O	1	c	E	O	A	4
27		L	O	2	g	E	O	N	1
28		L	O	1	a	E	U	U	3
29		L	O	1	b	E	N	N	5
30		L	O	1	g	E	U	U	1
31		L	O	1	g	E	U	U	1
32		L	O	1	a	E	N	A	3
33		L	O	3	g	M	N	N	1
					LANDSAT-4				
1		L	O	3	a	M	U	U	1
					MAGSAT				
1		L	L	1	d	O	N	A	2
2		L	O	2	d	U	U	A	1
3		L	O	1	d	E	N	A	1
4		L	O	1	d	U	U	U	4
5		L	O	2	g	E	N	A	1
6		L	O	2	e	U	N	A	1
7		L	O	1	d	O	N	A	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					NIMBUS-4				
1		L	O	1	d	O	U	U	3
2		L	O	1	c	E	U	U	3
					NIMBUS-5				
1		L	O	2	g	E	U	U	1
2		L	O	1	c	E	U	U	3
3		L	O	2	b	E	U	U	4
4		L	O	1	b	E	U	U	4
5		L	O	2	b	O	N	N	4
6		L	O	2	b	E	N	A	4
7		L	O	2	b	M	U	U	4
8		L	O	3	b	M	O	N	4
					NIMBUS-6				
1		L	O	1	g	E	U	U	1
2		L	O	2	g	M	U	U	1
3		L	O	1	g	M	U	U	1
4		L	O	1	d	E	U	U	1
5		L	O	1	a	E	U	U	1
6		L	O	1	b	U	U	U	4

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					NIMBUS-6				
7		L	O	1	g	O	U	A	1
8		L	O	3	c	E	U	U	3
					NIMBUS-7				
1		L	O	1	g	E	U	U	1
2		L	O	1	g	O	N	A	1
3		L	O	1	g	O	N	A	1
4		L	O	1	g	E	N	A	1
5		L	O	1	g	E	U	A	1
6		L	O	1	g	E	U	U	1
7		L	O	2	g	E	N	A	1
8		L	O	1	g	O	U	U	1
9		L	O	1	g	O	U	U	1
10		L	O	1	g	E	U	U	1
11		L	O	1	g	E	U	A	1
12		L	O	1	g	M	U	U	1
13		L	O	1	g	E	U	U	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					NIMBUS-7										NIMBUS-7				
14		L	O	1	g	E	U	U	1	32		L	O	1	g	O	U	U	1
15		L	O	1	g	E	U	U	1	33		L	O	1	g	O	N	A	1
16		L	O	1	a	O	U	U	1	34		L	O	1	a	O	N	A	3
17		L	O	1	g	M	N	A	1	35		L	O	1	g	E	O	N	1
18		L	O	1	a	O	N	N	1	36		L	O	2	a	E	N	N	3
19		L	O	1	g	O	N	A	1	37		L	O	1	g	O	U	U	1
20		L	O	1	d	E	N	A	1	38		L	O	1	g	E	N	A	1
21		L	O	1	g	E	U	U	1	39		L	O	1	d	O	N	A	1
22		L	O	1	g	E	U	U	1	40		L	O	1	g	E	U	U	1
23		L	O	1	a	E	U	U	1	41		L	O	1	b	E	U	U	4
24		L	O	1	g	E	U	U	1	42		L	O	1	g	E	U	U	1
25		L	O	1	g	E	U	U	1	43		L	O	1	g	E	U	U	1
26		L	O	1	g	E	U	U	1	44		L	O	2	g	M	U	U	1
27		L	O	2	g	E	N	A	1	45		L	O	1	c	E	N	A	3
28		L	O	2	c	E	U	U	3	46		L	O	1	b	E	U	U	5
29		L	O	2	g	O	N	A	1	47		L	O	1	g	O	N	A	1
30		L	O	1	c	E	N	A	3	48		L	O	1	d	O	U	U	2
31		L	O	1	b	M	U	U	4	49		L	O	1	b	E	N	A	5

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
NIMBUS-7									
50		L	O	1	b	O	N	A	4
51		L	O	1	g	O	N	A	1
52		L	O	1	g	E	U	U	1
53		L	O	1	b	E	N	U	5
54		L	O	2	g	E	U	U	1
55		L	O	2	f	E	N	A	1
56		L	O	1	b	E	N	A	5
57		L	O	1	g	O	N	A	1
58		L	O	1	d	E	U	U	1
59		L	O	1	a	O	N	A	3
60		L	O	1	g	E	U	U	1
61		L	O	1	g	O	N	A	1
NOAA-4									
1		L	O	2	g	M	O	N	1
2		L	O	2	g	M	O	N	1
3		L	O	1	g	O	N	A	3
4		L	O	3	d	E	O	N	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
NOAA-5									
1		L	O	2	g	M	O	A	1
2		L	O	2	g	M	O	A	1
3		L	O	1	g	O	U	U	1
4		L	O	1	g	O	U	U	1
5		L	O	1	g	O	U	U	1
6		L	O	1	g	O	N	A	1
7		L	O	3	g	M	U	U	1
8		L	O	2	g	O	N	A	1
NOAA-6									
1		L	L	2	d	O	N	A	2
2		L	L	2	a	O	N	A	4
3		L	L	1	d	E	U	U	2
4		L	L	1	d	E	N	A	1
5		L	L	1	b	O	N	A	5
6		L	L	1	d	O	U	U	1
7		L	L	1	d	M	N	A	5
8		L	L	1	f	O	N	A	1
9		L	O	1	f	O	N	A	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					NOAA-6				
10		L	O	1	d	O	U	U	2
11		L	O	1	g	E	U	U	1
12		L	O	2	g	E	N	A	1
13		L	O	2	b	M	U	U	4
14		L	O	2	d	O	U	U	1
15		I	O	1	b	O	U	U	4
16		L	O	2	b	O	U	U	4
17		L	O	1	g	O	U	U	1
18		L	O	2	b	O	O	N	4
19		L	O	2	g	O	N	N	1
20		L	O	1	g	E	U	U	1
21		L	O	1	d	O	U	U	1
22		L	O	2	g	E	O	A	1
23		L	O	1	d	O	U	U	1
					NOAA-7				
1		L	L	1	b	E	U	U	4
2		L	L	1	g	M	N	A	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					NOAA-7				
3		L	L	2	d	E	N	A	1
4		L	L	1	b	E	U	U	5
5		L	L	1	d*	O	U	U	2
6		L	O	1	g	E	N	A	1
7		L	O	2	d	O	U	U	1
8		L	O	1	d	O	U	U	1
9		L	O	1	g	O	U	U	1
10		L	O	1	g	E	U	U	1
11		L	O	1	g	E	N	A	1
					SMM				
1		L	L	1	g	E	U	U	1
2		L	L	1	g	E	U	U	1
3		L	L	2	g	E	N	A	1
4		L	L	1	g	O	N	A	1
5		L	L	1	d	O	N	A	1
6		L	L	1	g	O	U	U	1

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Anomaly Index	I	II	III	IV	V (SMM)	VIA	VIB	VII	VIII	Anomaly Index	I	II	III	IV	V (SMM)	VIA	VIB	VII	VIII
7		L	L	1	g	O	N	A	1	25		L	O	1	g	E	U	U	1
8		L	O	1	g	O	N	A	1	26		L	O	1	d	O	N	A	1
9		L	O	1	g	E	U	U	1	27		L	O	1	d	O	N	A	5
10		L	O	1	c	E	U	U	1	28		L	O	1	g	O	N	A	4
11		L	O	1	g	M	N	A	1	29		L	O	1	g	E	U	U	1
12		L	O	1	g	[illegible]	U	U	1	30		L	O	1	d	E	N	A	1
13		L	O	1	g	O	N	A	1	31		L	O	2	g	E	O	A	1
14		L	O	1	a	E	N	N	5	32		L	O	1	g	E	U	U	1
15		L	O	2	g	E	O	N	1	33		L	O	2	d	O	N	A	1
16		L	O	1	b	O	U	U	4	34		L	O	2	g	U	U	U	1
17		L	O	1	d	O	U	U	1	35		L	O	1	d	O	N	A	1
18		L	O	1	d	O	N	A	5	36		L	O	4	d	O	N	A	1
19		L	O	1	b	O	U	U	1	37		L	O	1	d	E	U	U	1
20		L	O	1	g	M	O	N	1	38		L	O	1	d	E	U	U	1
21		L	O	1	d	O	N	A	5	39		L	O	1	d	E	U	U	1
22		L	O	1	b	E	C	N	4	40		L	O	1	g	E	U	U	1
23		L	O	1	a	E	U	U	5	41		L	O	1	g	M	U	U	1
24		L	O	1	d	O	N	A	5	42		L	O	1	g	M	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
SMM									
43		L	O	1	g	O	N	N	1
44		L	O	1	f	O	O	A	1
45		L	O	1	g	O	U	U	1
SMS-1									
1		L	O	2	b	E	U	U	5
2		L	O	1	b	O	N	A	5
3		L	O	3	b	E	U	U	5
SMS-2									
1		L	O	2	b	U	U	U	5
2		L	O	1	b	E	U	U	1
3		L	O	1	g	E	O	N	1
4		L	O	4	g	E	O	N	1
5		L	O	1	c	O	U	U	3
6		L	O	1	c	E	U	U	3
7		L	O	2	d	O	N	U	2
8		L	O	2	b	E	O	N	5
TIROS-N									
1		L	L	1	d	O	N	A	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
TIROS-N									
2		L	L	1	c	E	O	N	3
3		L	L	1	e	O	N	A	1
4		L	L	2	d	O	O	A	1
5		L	L	1	e	O	N	A	1
6		L	L	1	e	E	O	N	1
7		L	L	1	g	M	O	A	1
8		L	L	2	g	O	U	U	1
9		L	L	1	b	E	N	A	5
10		L	L	1	d	O	N	A	5
11		L	L	1	e	E	U	U	1
12		L	L	1	g	E	U	U	1
13		L	L	1	a	O	N	N	3
14		L	O	2	d	O	N	A	5
15		L	O	1	a	E	U	A	3
16		L	O	1	a	O	N	A	3
17		L	O	1	d	O	N	A	5
18		L	O	1	g	O	U	U	1
19		L	O	2	b	E	U	U	5

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					TIROS-N										TIROS-N				
20		L	O	1	c	E	U	U	3	38		L	O	1	g	E	N	A	1
21		L	O	2	b	O	U	U	4	39		L	O	1	d	O	N	N	1
22		L	O	1	a	O	O	A	4	40		L	O	2	g	E	C	N	1
23		L	O	1	g	O	N	A	1	41		L	O	3	d	O	U	U	1
24		L	O	1	d	O	U	U	1	42		L	O	2	d	O	U	U	1
25		L	O	1	g	O	N	A	1	43		L	O	5	d	E	O	U	1
26		L	O	1	g	O	N	A	1						SEASAT				
27		L	O	1	b	O	U	U	1	1		L	L	1	b	O	N	N	5
28		L	O	1	g	O	U	U	1	2		L	L	1	d	O	N	A	1
29		L	O	1	d	O	N	A	5	3		L	O	1	b	O	N	A	1
30		L	O	1	d	O	U	U	1	4		L	O	1	d	O	N	A	1
31		L	O	1	a	E	N	U	4	5		L	O	1	d	E	N	U	1
32		L	O	1	g	O	N	N	1	6		L	O	1	d	E	N	A	1
33		L	O	1	d	O	N	N	1	7		L	O	1	d	E	U	U	1
34		L	O	1	c	O	O	A	3	8		L	O	2	d	E	U	U	1
35		L	O	2	d	E	U	U	1	9		L	O	2	b	E	U	U	1
36		L	O	2	c	E	O	N	3	10		L	O	1	d	O	U	U	1
37		L	O	1	b	O	O	N	4	11		L	O	1	d	E	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					SEASAT				
12		L	O	2	d	O	N	A	1
13		L	O	1	d	O	U	U	1
14		L	O	1	g	M	U	U	1
15		L	O	1	c	E	N	N	3
16		L	O	1	d	O	N	A	1
17		L	O	1	b	E	N	A	5
18		L	O	[illegible]	b	E	U	U	4
19		L	O	1	g	E	N	U	1
20		L	O	1	g	O	N	N	1
21		L	O	5	c	E	N	A	3
22		L	O	1	d	O	N	A	1
					SME				
1		L	L	1	g	O	N	A	1
2		L	L	2	e	O	N	A	1
3		L	L	1	b	M	U	U	4
4		L	L	1	g	O	U	U	1
5		L	O	1	c	E	U	U	3
6		L	O	1	g	E	U	U	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					VIKING ORBITER 1				
1		L	O	1	a	E	U	U	3
2		L	O	1	d	O	N	N	1
					VIKING LANDER 1				
1		L	L	1	c	O	N	A	3
2		L	L	1	d*	M	C	N	2
3		L	O	1	c	E	N	A	3
4		L	O	2	g	E	U	U	1
5		L	O	1	c	O	N	N	3
6		L	O	1	b	E	O	N	5
7		L	O	1	g	O	N	A	1
8		L	O	1	g	M	N	A	1
9		L	O	2	g	E	N	A	1
10		L	O	1	g	O	U	U	1
11		L	O	1	g	E	N	N	1
12		L	O	1	b	O	N	A	5
13		L	O	1	b	E	U	U	4
14		L	O	1	g	O	N	A	1
15		L	O	1	b	E	N	A	5

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					VIKING LANDER 1				
16		L	O	2	d	E	U	U	1
17		L	O	1	b	E	U	U	4
					VIKING ORBITER 2				
1		L	O	2	a	E	N	A	1
2		L	O	1	d	M	U	U	1
3		L	O	1	d	M	U	U	1
4		L	O	5	d	M	U	U	1
					VIKING LANDER 2				
1		L	O	1	d*	M	O	A	2
2		L	O	1	d	O	N	A	1
3		L	O	1	a	E	N	A	3
4		L	O	1	d	E	U	U	1
5		L	O	1	g	O	U	A	1
6		L	O	1	g	E	O	N	1
7		L	O	1	d	O	N	A	1
8		L	O	1	b	O	N	A	4
9		L	O	2	g	O	N	N	1
10		L	O	2	b	O	N	A	5

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					VIKING LANDER 2				
11		L	O	1	g	M	U	U	1
12		L	O	2	b	E	N	N	5
13		L	O	5	b	U	U	U	4
					VOYAGER 1				
1		L	L	1	d*	M	N	A	1
2		L	O	1	d*	E	N	A	2
3		L	O	2	d*	O	N	A	2
4		L	O	1	b	O	C	N	4
5		L	O	1	d	O	N	A	2
6		L	O	1	b	E	O	A	5
7		L	O	1	b	O	N	A	4
8		L	O	1	d	O	N	A	1
9		L	O	1	g	M	U	U	1
10		L	O	1	a	E	N	A	5
11		L	O	2	d	O	U	U	1
12		L	O	1	b	E	N	A	1
13		L	O	1	d	O	N	A	1
14		L	O	2	d	O	N	A	1

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Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					VOYAGER 1				
15		L	O	1	g	E	O	A	1
16		L	O	2	g	E	C	N	1
17		L	O	2	b	O	C	N	4
18		L	O	1	g	O	U	U	1
					VOYAGER 2				
1		L	L	1	g	M	N	A	1
2		L	L	1	c	E	C	N	4
3		L	L	1	b	E	N	A	2
4		L	L	1	d	O	N	A	1
5		L	L	1	d	O	N	N	1
6		L	L	1	d	O	N	A	1
7		L	L	1	d	O	N	A	1
8		L	L	1	g	O	N	A	1
9		L	O	1	d	O	N	N	3
10		L	O	2	d*	O	N	A	2
11		L	O	1	d*	M	N	A	1
12		L	O	2	g	E	C	N	1
13		L	O	2	b	E	O	N	1

Anomaly Index	I	II	III	IV	V	VIA	VIB	VII	VIII
					VOYAGER 2				
14		L	O	2	g	E	N	A	1
15		L	O	1	b	E	O	A	5
16		L	O	1	b	E	N	A	5
17		L	O	1	g	O	N	A	1
18		L	O	2	a	E	O	N	1
19		L	O	1	a	E	C	N	1
20		L	O	1	e	O	N	A	1
21		L	O	2	●	E	N	A	4
22		L	O	1	a	E	C	N	1
23		L	O	1	g	M	C	N	1
24		L	O	1	g	E	C	N	1
25		L	O	2	b	E	C	N	4
26		L	O	3	g	M	N	A	1
27		L	O	1	d	M	N	A	1

APPENDIX B-3

ANOMALY CLASSIFICATIONS
ADDITIONAL CHARACTERISTICS

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ANOMALOUS INCIDENT CLASSIFICATION CODES,
ADDED CHARACTERISTICS

X. Anomaly Cause

a. Space Environment
b. On-Board Software
c. Design, Other
d. Quality Control/Workmanship
e. Contamination
f. Catastrophic Part Failure
g. Catastrophic Circuit Failure
h. Catastrophic Component Failure
i Catastrophic Black Box Failure
j Unknown

TOTAL

XI. Anomaly Type

S. Systematic
W. Wearout/Aging/Depletion
C. Chance
G. Glitch
U. Unknown

TOTAL

XII. Testability

Y. Yes
N. No
M. Maybe
U. Unknown

TOTAL

XIII. Source

1. Part
2. Circuit/Subassembly
3. Component
4. Black Box
5. Subsystem/Interface
6. Interaction
7. Unknown

TOTAL

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Anomaly Index	X	XI	XII	XIII
		AE-5		
1	c	S	Y	6
2	d	S	Y	5
3	j	U	U	7
4	j	U	U	3
5	j	U	U	4
6	j	U	U	3
7	c	S	M	5
		AEM-1 (HCCM)		
1	j	U	U	3
2	c	S	Y	3
3	c	S	Y	5
4	c	S	Y	2
5	c	S	Y	2
6	d	S	M	3
7	d	S	Y	1
8	j	U	U	6
9	c	W	M	4
10	e	W	U	2

Anomaly Index	X	XI	XII	XIII
		AE-1(HCCM)		
11	j	U	U	7
12	a	S	U	2
13	j	U	U	3
		AEM-2 (SAGE)		
1	a	S	M	5
2	c	S	M	5
3	a	S	Y	5
4	c	S	Y	6
5	c	S	M	3
6	c	W	M	4
7	g	C	U	2
8	j	G	U	7
9	a	S	M	6
10	j	W	N	2
		ATS-1		
1	j	W	U	7
2	j	U	U	7
3	j	W	U	7

Anomaly Index	X	XI	XII	XIII
		ATS-1		
4	j	W	U	4
5	j	W	U	4
		ATS-3		
1	h	U	U	3
2	j	W	U	7
3	j	W	U	4
4	j	W	U	4
		ATS-5		
1	c	S	Y	2
2	a	S	N	4
3	f	C	N	1
4	c	S	N	3
5	f	W	N	4
6	c	S	N	5
7	j	W	N	3
8	j	W	U	4
9	j	W	U	4

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Anomaly Index	X	XI	XII	XIII
		ATS-6		
1	j	U	U	4
2	e	S	Y	3
3	e	S	Y	3
4	e	S	Y	3
5	e	S	Y	3
6	i	U	U	4
7	e	S	Y	3
8	j	U	U	5
9	e	S	Y	3
10	e	S	Y	3
11	e	S	Y	3
12	e	S	Y	3
13	e	S	Y	3
14	e	S	Y	3
15	e	S	Y	3
16	e	S	Y	3
17	g	C	U	2
18	a	W	U	1

Anomaly Index	X	XI	XII	XIII
		ATS-6		
19	e	S	Y	3
20	e	S	Y	3
21	h	C	U	3
22	c	S	Y	6
23	j	W	U	4
24	a	S	Y	4
25	c	S	Y	3
26	a	S	Y	3
		DE-1		
1	c	S	Y	6
2	c	S	Y	5
3	c	S	Y	6
4	j	U	U	3
5	j	U	U	3
6	j	G	U	7
7	j	U	U	3
8	j	G	U	7
9	j	G	U	7

Anomaly Index	X	XI	XII	XIII
		DE-1		
10	j	G	U	3
11	d	S	M	1
12	f	C	U	1
13	j	S	M	3
14	a	S	M	1
		DE-2		
1	g	U	U	2
2	j	U	U	2
3	j	U	U	3
4	j	U	M	6
5	j	U	M	2
6	c	S	M	6
7	c	S	M	6
8	j	U	U	2
9	d	S	M	1
10	j	S	M	3
		GOES-1		
1	i	U	U	4

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		GOES-1					GOES-3					GOES-4		
2	j	U	U	4	8	a	U	M	4	15	c	S	M	3
3	h	U	U	3	9	f	W	M	1	16	j	U	M	6
4	j	U	U	4	10	f	U	U	1	17	c	S	Y	4
5	f	C	U	1	11	f	U	U	1	18	a	S	N	6
		GOES-2					GOES-4			19	i	C	Y	4
1	f	C	U	1	1	c	S	Y	5	20	d	C	M	2
2	h	S	M	3	2	c	S	Y	5	21	a	U	M	4
3	h	S	M	3	3	j	U	M	4	22	c	S	Y	6
4	t	C	U	1	4	d	S	Y	4	23	j	G	U	7
5	j	U	U	4	5	j	U	U	3	24	h	U	U	3
6	g	C	U	2	6	c	S	M	3	25	a	S	N	4
		GOES-3			7	j	U	M	6	26	c	S	Y	6
1	j	U	M	3	8	c	S	Y	3	27	j	S	M	7
2	h	U	U	3	9	c	S	Y	5	28	j	U	U	4
3	c	S	M	3	10	g	U	U	2	29	j	U	M	6
4	j	U	U	3	11	c	S	M	6	30	j	U	M	7
5	j	U	U	3	12	d	S	M	4	31	j	G	U	3
6	h	S	M	3	13	f	C	M	1	32	j	U	U	2
7	j	U	U	3	14	c	S	Y	6					

Anomaly Index	X	XI	XII	XIII
		GOES-5		
1	c	S	Y	6
2	g	C	Y	2
3	j	U	U	6
4	g	U	U	2
5	g	U	U	2
6	c	S	Y	6
7	j	W	M	1
8	i	C	Y	4
9	a	S	N	4
10	j	U	U	3
11	j	U	M	2
12	j	C	U	2
13	j	S	M	7
14	j	U	U	7
15	j	S	M	7
16	j	S	M	7
17	c	S	Y	6
		IMP-8		
1	h	U	U	3

Anomaly Index	X	XI	XII	XIII
		ISEE-1		
1	c	S	Y	2
2	h	U	U	3
3	a	S	Y	3
4	g	U	U	2
5	h	U	U	3
6	a	U	M	6
7	j	U	U	3
8	j	G	N	3
9	j	G	N	6
10	j	G	N	6
11	j	U	U	3
12	i	W	U	4
		ISEE-2		
1	j	U	U	6
2	h	U	U	3
3	c	W	Y	2
		ISEE-3		
1	h	U	U	3
2	h	U	U	3

Anomaly Index	X	XI	XII	XIII
		ISEE-3		
3	h	U	U	3
4	h	U	U	3
5	j	C	N	6
6	i	U	U	4
7	i	W	U	4
		IUE		
1	f	C	N	1
2	c	S	Y	6
3	b	S	Y	6
4	c	S	Y	6
5	h	U	U	3
6	g	U	U	2
7	c	S	Y	1
8	j	G	N	6
9	f	U	M	1
10	j	U	U	7
11	i	S	M	4
12	c	S	Y	6
13	j	U	M	2

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		IUE					LANDSAT-2					LANDSAT-3		
14	c	S	Y	6	7	j	G	M	6	8	j	U	U	7
15	j	U	U	4	8	h	W	M	3	9	b	S	Y	6
16	j	G	N	7	9	j	W	M	4	10	b	S	Y	6
17	j	U	U	3	10	g	U	U	2	11	j	U	U	7
18	j	G	N	7	11	i	W	U	4	12	j	U	U	7
19	j	S	M	4	12	j	W	U	4	13	j	G	N	6
20	f	S	M	1	13	j	G	N	1	14	j	U	U	3
21	j	G	N	6	14	j	G	N	7	15	b	S	Y	6
22	i	S	M	4	15	h	W	M	3	16	j	U	U	7
23	j	S	M	4	16	h	U	U	3	17	c	S	Y	6
24	i	S	M	4			LANDSAT-3			18	a	S	M	6
		LANDSAT-2			1	a	U	Y	6	19	c	S	M	3
1	j	W	U	4	2	j	U	M	6	20	j	U	U	3
2	a	U	S	5	3	f	U	U	1	21	j	U	U	7
3	d	S	M	2	4	j	U	U	4	22	j	G	U	6
4	j	G	N	6	5	j	U	U	3	23	g	U	U	2
5	i	U	U	4	6	g	U	U	2	24	i	G	U	6
6	i	W	M	4	7	a	S	M	6	25	j	G	U	6

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Anomaly Index	X	XI	XII	XIII
		LANDSAT-3		
26	j	U	U	6
27	h	U	U	3
28	g	U	U	2
29	i	W	N	3
30	j	U	U	4
31	j	U	U	3
32	j	U	U	6
33	j	W	U	3
		LANDSAT-4		
1	j	U	U	7
		MAGSAT		
1	c	S	Y	2
2	d	S	Y	2
3	j	U	U	1
4	j	U	U	5
5	j	S	M	6
6	a	U	N	6
7	a	S	U	6

Anomaly Index	X	XI	XII	XIII
		NIMBUS-4		
1	j	U	N	6
2	i	W	N	4
		NIMBUS-5		
1	h	U	U	3
2	i	W	N	4
3	j	U	U	4
4	j	W	N	4
5	j	W	N	4
6	j	W	N	3
7	i	W	N	4
8	i	W	N	4
		NIMBUS-6		
1	h	U	U	3
2	f	U	U	1
3	h	U	U	3
4	j	U	U	6
5	j	G	N	6
6	i	U	U	4

Anomaly Index	X	XI	XII	XIII
		NIMBUS-6		
7	j	U	N	7
8	i	W	N	4
		NIMBUS-7		
1	j	G	U	7
2	j	U	M	3
3	c	S	Y	6
4	c	S	Y	6
5	j	S	N	6
6	a	S	Y	6
7	2	U	M	6
8	g	U	Y	2
9	j	U	M	6
10	a	U	Y	6
11	j	U	Y	3
12	j	G	Y	3
13	j	G	Y	6
14	c	S	Y	6
15	j	U	U	7

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		NIMBUS-7					NIMBUS-7					NIMBUS-7		
16	j	G	Y	6	34	j	U	U	3	52	j	G	N	7
17	j	U	U	3	35	a	S	M	4	53	h	U	U	3
18	j	U	U	7	36	j	U	U	7	54	a	S	M	4
19	a	S	M	4	37	c	W	Y	4	55	j	U	U	7
20	j	G	N	7	38	q	U	U	2	56	j	G	M	7
21	j	G	U	7	39	j	U	U	4	57	c	S	Y	2
22	j	U	U	2	40	j	U	U	2	58	a	S	M	6
23	a	S	U	6	41	c	S	M	6	59	e	S	M	3
24	j	U	U	7	42	q	U	U	2	60	j	G	U	6
25	a	U	U	3	43	f	U	U	1	61	j	U	U	7
26	c	S	M	6	44	e	W	M	6			NOAA-4		
27	j	U	U	7	45	j	U	U	2	1	i	U	U	4
28	j	U	U	3	46	c	S	Y	4	2	i	U	U	4
29	j	U	U	3	47	c	S	Y	6	3	i	U	U	4
30	a	S	U	6	48	j	U	U	3	4	j	G	U	6
31	j	U	U	3	49	j	U	U	4			NOAA-5		
32	j	U	U	3	50	j	G	N	7	1	i	U	U	4
33	j	G	U	7	51	j	G	N	7	2	i	U	U	4

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		NOAA-5					NOAA-6					NOAA-7		
3	j	U	U	4	12	c	S	M	2	6	d	S	M	6
4	i	U	U	4	13	f	U	U	1	7	j	U	U	7
5	i	U	U	4	14	j	U	U	7	8	a	S	N	6
6	j	U	U	4	15	j	U	U	4	9	j	U	U	7
7	i	U	U	4	16	j	U	U	4	10	j	G	U	7
8	j	S	U	7	17	j	U	U	3	11	c	S	M	6
		NOAA-6			18	f	C	N	1			SMM		
1	c	S	M	6	19	j	W	M	3	1	j	U	M	2
2	c	S	N	6	20	j	G	U	7	2	c	S	M	6
3	f	U	U	1	21	j	U	U	3	3	j	S	M	2
4	j	G	U	7	22	f	S	Y	1	4	e	S	M	3
5	d	S	Y	2	23	j	U	U	4	5	c	S	M	5
6	j	G	U	7			NOAA-7			6	f	S	M	1
7	b	S	N	6	1	i	U	U	4	7	a	S	M	6
8	c	S	Y	6	2	j	U	U	3	8	j	G	U	7
9	e	S	N	6	3	a	S	N	6	9	j	U	U	7
10	j	U	U	7	4	j	U	U	7	10	a	S	N	6
11	j	U	U	7	5	j	U	U	7	11	b	S	M	6

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		SMM					SMM					SMS-1		
12	j	G	U	7	30	a	S	N	1	2	j	U	U	6
13	j	U	U	3	31	j	U	U	1	3	j	U	U	4
14	a	S	N	6	32	j	U	U	7			SMS-2		
15	j	U	U	3	33	c	S	Y	1	1	j	U	U	4
16	j	U	N	7	34	c	S	Y	1	2	g	C	N	2
17	j	U	U	3	35	j	U	U	7	3	f	U	U	1
18	b	S	M	6	36	c	S	Y	1	4	g	C	N	2
19	a	S	N	2	37	j	U	U	7	5	f	U	U	1
20	i	U	U	4	38	j	U	U	7	6	f	U	U	1
21	b	S	U	6	39	j	U	U	4	7	j	U	U	7
22	f	C	N	1	40	j	U	U	4	8	j	U	U	7
23	j	G	U	7	41	j	U	U	4			TIROS-N		
24	b	U	U	7	42	j	U	N	6	1	d	S	M	2
25	j	U	U	7	43	j	U	U	7	2	c	S	N	6
26	a	S	N	6	44	c	S	N	6	3	c	S	M	6
27	j	U	U	7	45	j	U	U	3	4	a	S	N	1
28	j	U	U	7			SMS-1			5	e	S	N	6
29	i	U	U	4	1	j	U	U	4	6	c	S	N	2

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		TIROS-N					TIROS-N					TIROS-N		
7	c	S	N	3	25	a	S	N	6	43	h	U	U	3
8	h	U	U	3	26	j	U	U	6			SEASAT		
9	c	S	N	6	27	f	U	U	1	1	b	S	M	6
10	b	S	M	6	28	b	S	N	6	2	c	S	M	6
11	d	S	Y	2	29	j	G	U	7	3	j	U	U	1
12	j	U	U	4	30	j	U	U	4	4	a	S	N	1
13	j	G	U	6	31	i	U	U	4	5	j	U	U	2
14	b	S	M	6	32	a	S	N	6	6	o	S	Y	2
15	b	S	M	6	33	j	U	U	2	7	f	U	Y	1
16	b	S	M	6	34	d	S	M	4	8	b	S	M	6
17	b	S	M	6	35	h	U	U	3	9	g	U	Y	2
18	j	U	U	3	36	d	S	M	4	10	j	U	U	7
19	j	U	U	3	37	j	U	U	2	11	j	G	U	7
20	j	G	U	7	38	j	G	U	6	12	a	U	M	6
21	j	G	U	7	39	f	U	U	1	13	j	U	U	7
22	a	S	N	6	40	j	W	U	3	14	f	U	U	1
23	j	U	U	4	41	j	U	U	4	15	j	U	U	7
24	b	S	N	6	42	a	U	N	6	16	c	S	M	6

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Anomaly Index	X	XI	XII	XIII
		SEASAT		
17	j	U	U	7
18	j	U	U	7
19	c	S	M	6
20	j	G	U	7
21	c	S	M	2
22	a	U	U	6
		SME		
1	a	S	U	4
2	c	S	Y	6
3	j	S	Y	4
4	j	U	U	6
5	j	U	U	7
6	j	U	U	4
		VIKING ORBITER 1		
1	j	U	U	7
2	a	S	N	6
		VIKING LANDER 1		
1	d	S	Y	1

Anomaly Index	X	XI	XII	XIII
		VIKING LANDER 1		
2	f	U	U	1
3	c	S	Y	6
4	j	U	U	7
5	a	S	N	6
6	d	S	Y	2
7	j	U	U	6
8	b	S	N	6
9	j	U	N	3
10	j	U	N	3
11	d	S	M	2
12	j	U	U	6
13	j	U	U	7
14	f	U	U	1
15	g	U	U	2
16	g	U	U	2
17	j	U	U	7
		VIKING ORBITER 2		
1	j	U	U	6

Anomaly Index	X	XI	XII	XIII
		VIKING ORBITER 2		
2	j	U	U	3
3	j	U	U	3
4	j	U	U	3
		VIKING LANDER 2		
1	j	U	U	6
2	b	S	N	6
3	d	S	Y	1
4	j	U	M	2
5	j	U	M	1
6	f	U	U	1
7	j	U	U	6
8	j	U	U	6
9	j	G	U	6
10	c	S	U	6
11	j	U	U	4
12	f	U	U	1
13	i	U	U	4

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Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII	Anomaly Index	X	XI	XII	XIII
		VOYAGER 1					VOYAGER 2					VOYAGER 2		
1	c	S	N	6	1	j	S	N	7	19	f	U	U	1
2	c	S	N	6	2	f	U	U	1	20	j	U	U	6
3	c	S	N	6	3	c	S	M	6	21	a	S	N	6
4	g	U	U	2	4	a	S	N	6	22	f	U	U	1
5	d	S	M	1	5	a	S	N	6	23	f	U	U	1
6	d	S	M	1	6	c	S	N	6	24	d	S	U	1
7	j	U	U	6	7	a	S	N	6	25	g	U	U	2
8	c	S	U	2	8	b	S	M	6	26	j	W	U	3
9	j	S	N	6	9	j	U	U	7	27	j	U	N	6
10	a	U	U	7	10	c	S	N	6					
11	j	U	U	7	11	c	S	N	6					
12	j	U	U	2	12	f	U	U	1					
13	c	S	M	6	13	j	U	U	1					
14	a	S	N	1	14	c	S	M	1					
15	j	U	U	2	15	d	S	M	1					
16	f	U	U	1	16	c	S	Y	6					
17	f	U	U	1	17	d	S	M	1					
18	j	U	U	1	18	g	U	U	2					

APPENDIX C

PERFORMANCE SUMMARIES

APPENDIX C

PERFORMANCE SUMMARIES

This appendix presents spacecraft and major spacecraft subsystem performance summaries in graphical form. Appendix C-1 contains one chart per spacecraft, although some charts run to two or even three pages. Each chart identifies all of the spacecraft's subsystems and payloads. It further identifies each anomalous component within the subsystem or payload. All anomalies are identified on the chart at the time they occurred. Those that caused complete failure of the associated component are denoted by a circle; all others by triangles. Anomaly indications in the "Unknown Time of Occurrence" column are of essentially negligible mission effect and occur at some undocumented time(s) or are present throughout the mission. Survival times are also given for each subsystem and anomalous component. When an anomalous component is redundant, the survival times are given for the redundant units even if they have no anomalies. Other components without anomalies are not listed.

Appendix C-2 arrays significant anomalies and failures by major spacecraft subsystems. Since each program has a somewhat different breakout of subsystems, we have standardized on the eight defined in subsection III.A.5. In addition to being ordered by subsystem rather than spacecraft, this appendix differs from Appendix C-1 in two ways. First, only "significant" anomalies are included. These are generally those categorized as having a mission effect code of 2 or greater (see subsection III.A.4) although all anomalies in redundant units, whose mission effect is negligible because of the redundancy, are also included. The second major difference is that time, rather than being plotted in hours as in Appendix C-1, is plotted in terms of spacecraft design life. For the major subsystems (Timing, Control and Command; Telemetry and Data Handling; Power Supply; Attitude Control and Stabilization; and Payload) an entry is made for each spacecraft whether or not it had significant anomalies in the subject subsystem. Note that an entry of "No significant anomalies" means on that subsystem only. The Structure subsystem does not appear since there were no significant anomalies in this subsystem in this update. Furthermore, for the Propulsion and the Environmental Control subsystems only those spacecraft are listed which suffered significant anomalies in these areas.

APPENDIX C-1

SPACECRAFT

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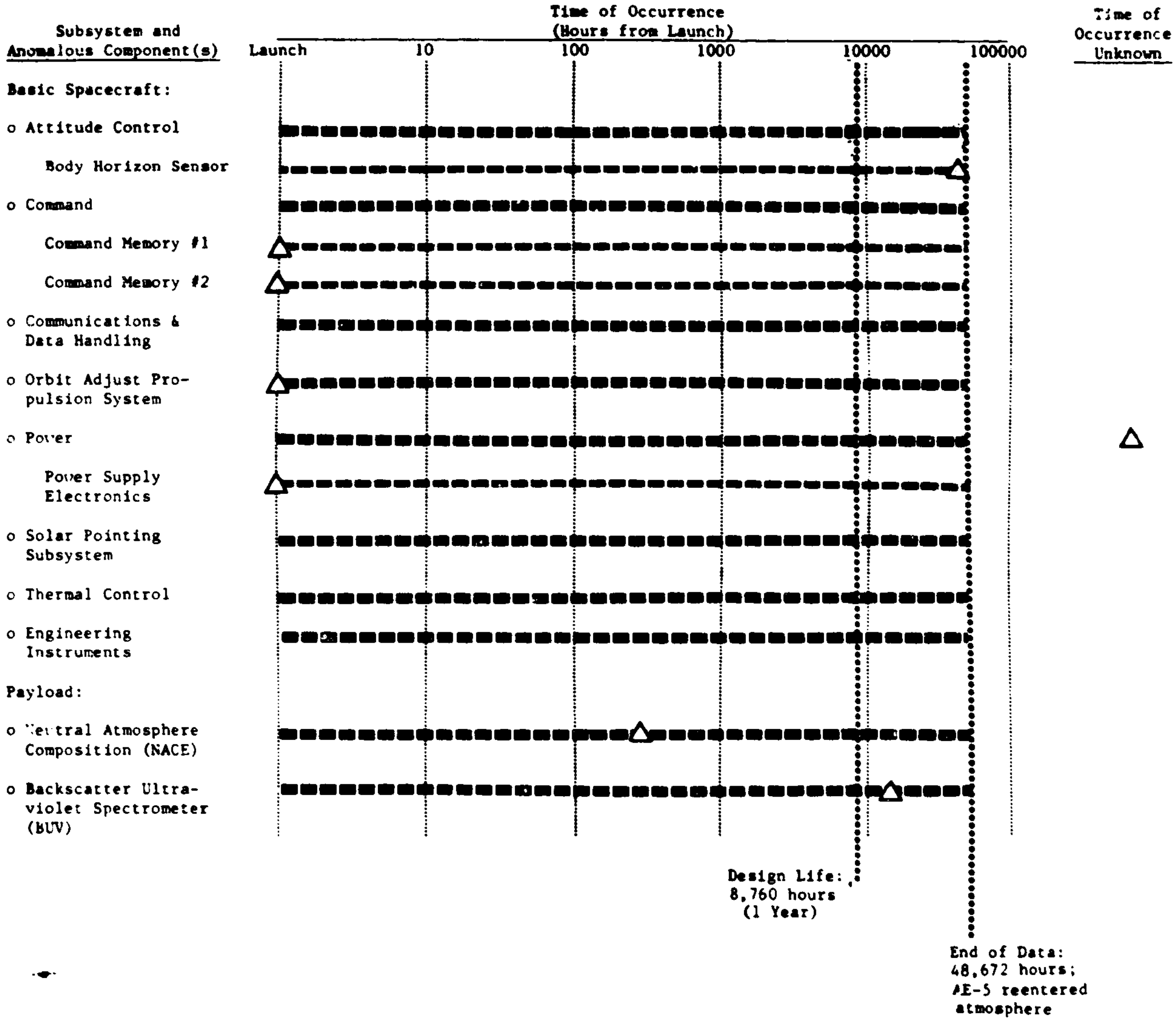
PERFORMANCE SUMMARY FOR AE-5



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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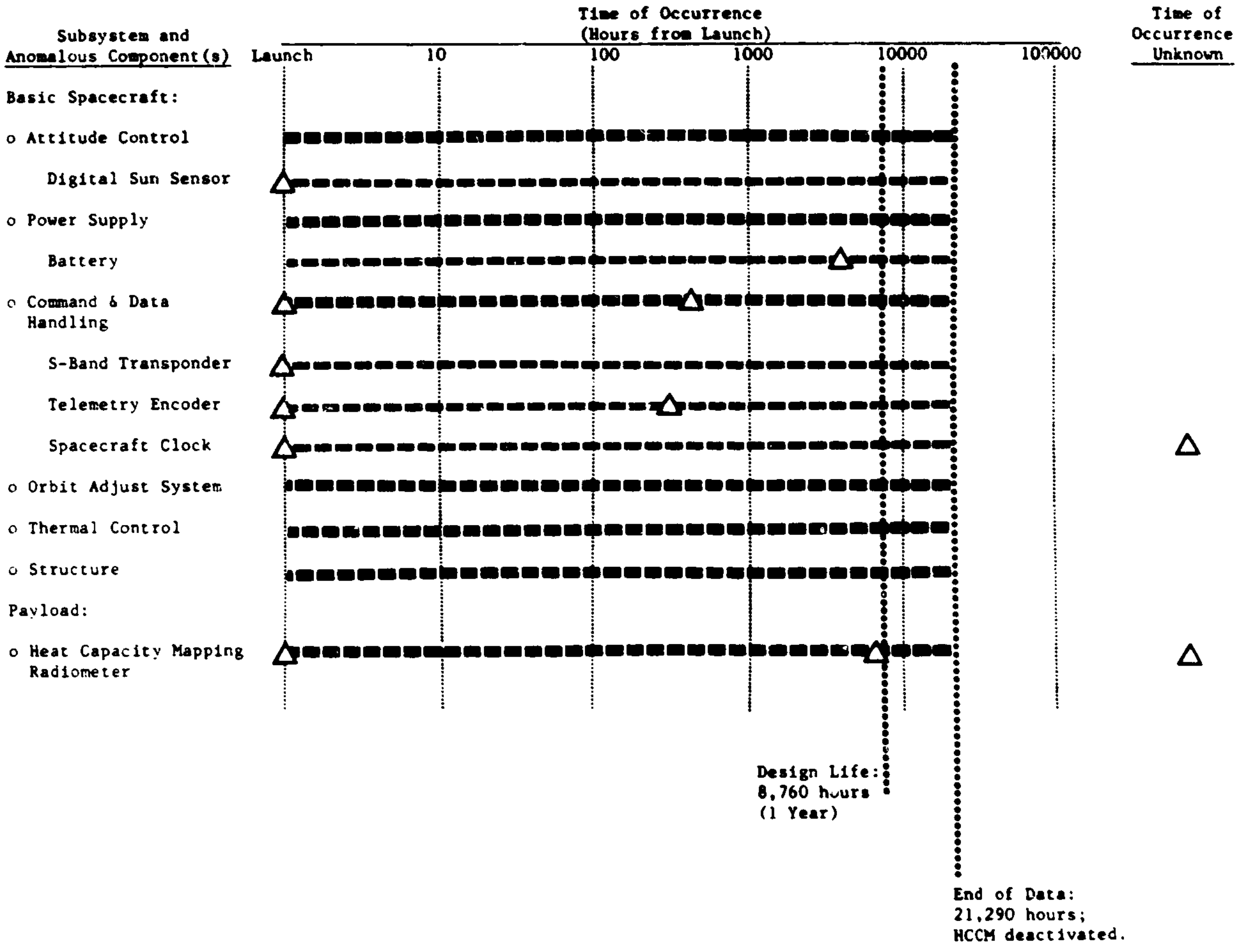
PERFORMANCE SUMMARY FOR AEM-1 (HCCM)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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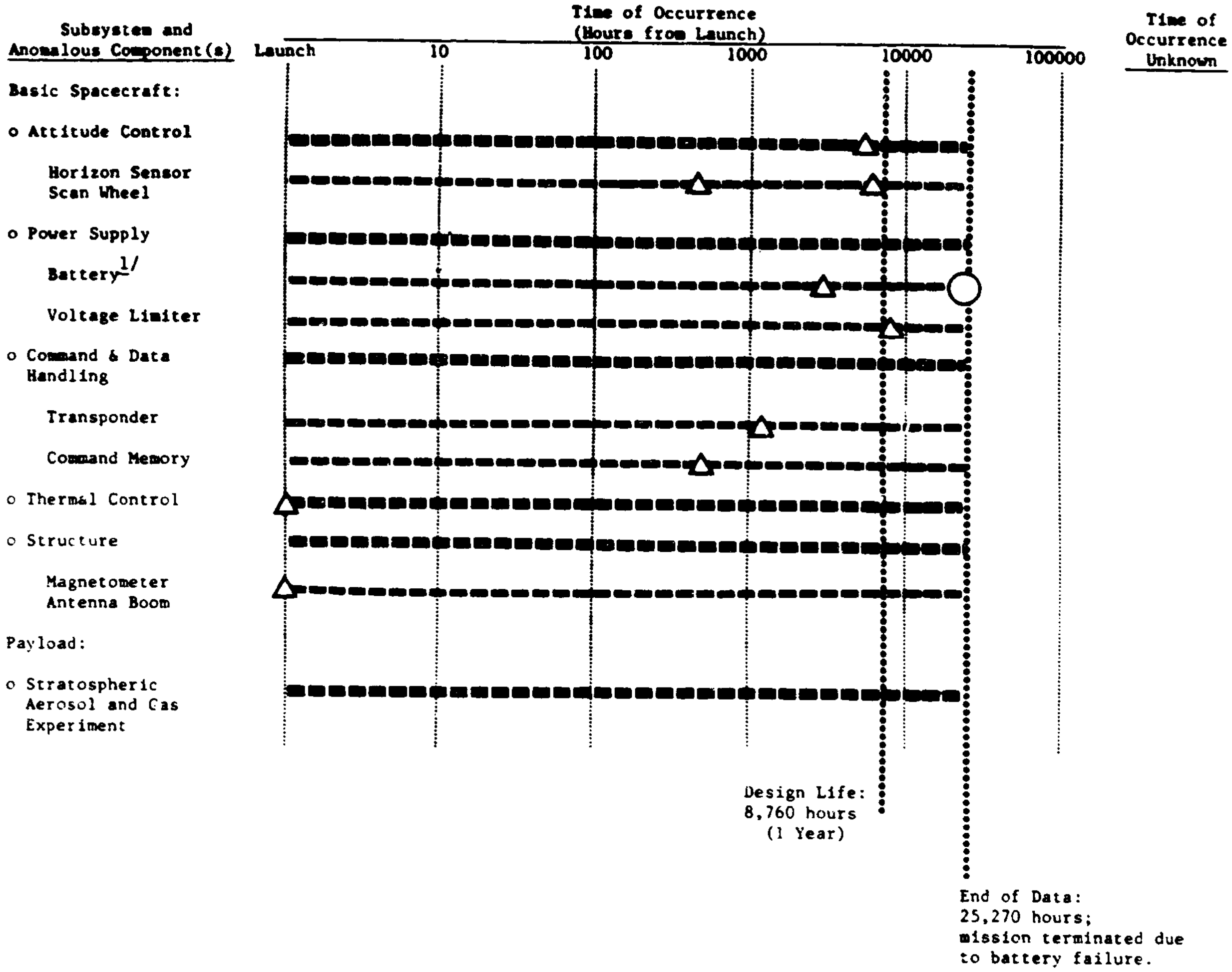
PERFORMANCE SUMMARY FOR AEM-2 (SAGE)



Legend:

○ indicates that that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or the component unusable.

△ indicates that this anomaly is not a failure.

1/ Battery capacity started to degrade at 2050 hours and failed completely at 25,270 hours.

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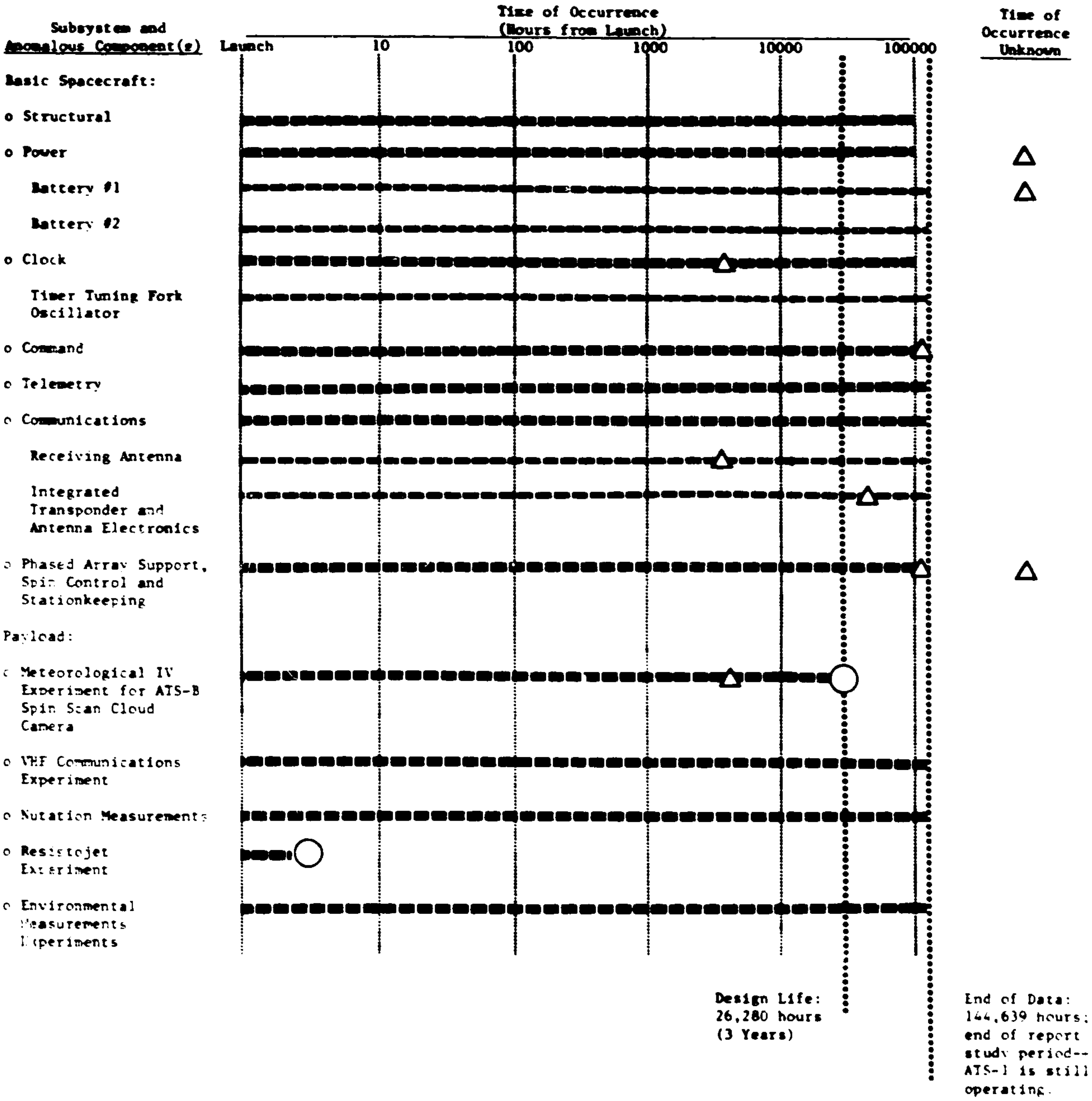
PERFORMANCE SUMMARY FOR ATS-1



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

C-3

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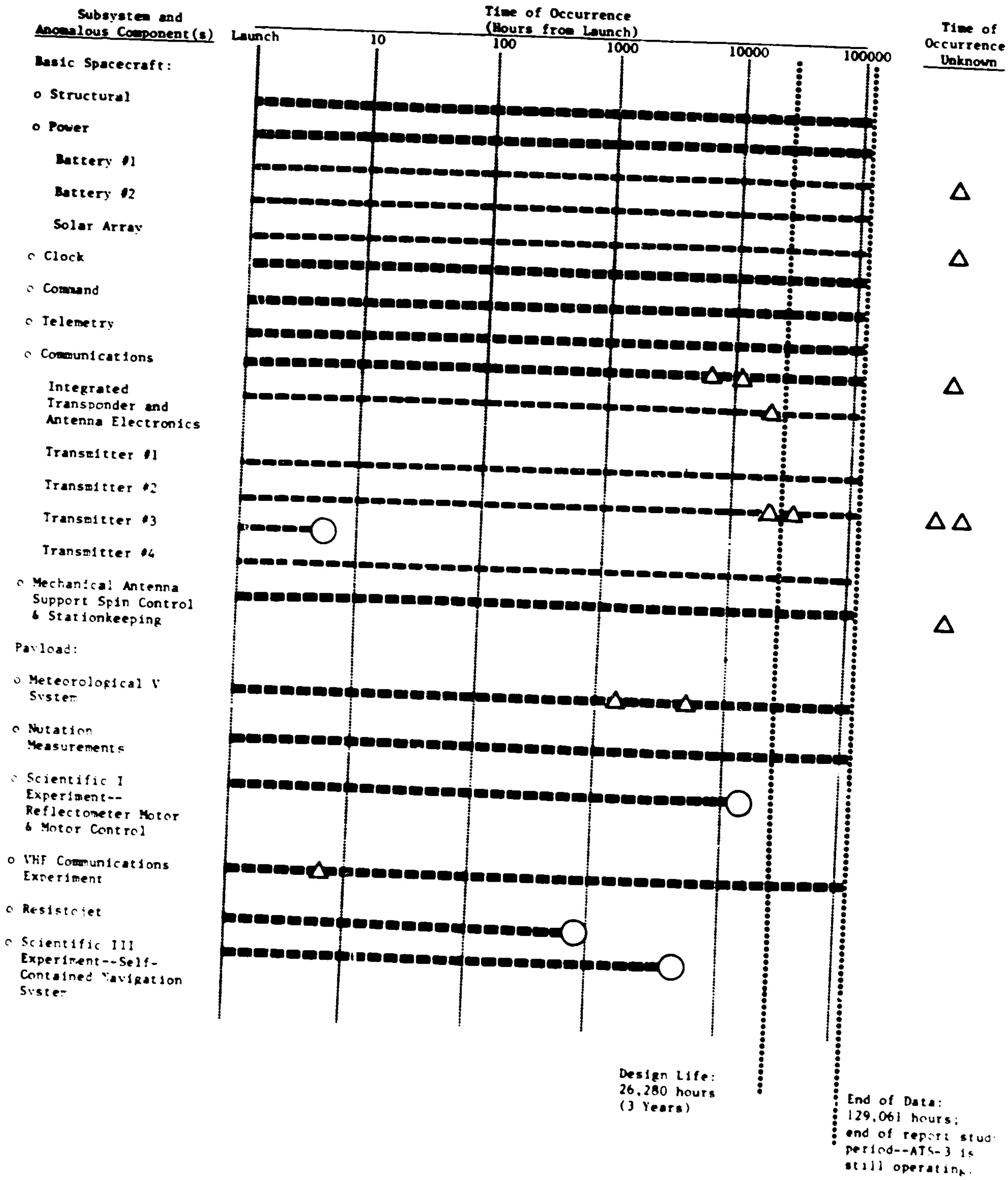
PERFORMANCE SUMMARY FOR ATS-3



Legend:

△ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

○ indicates that this anomaly is not a failure.

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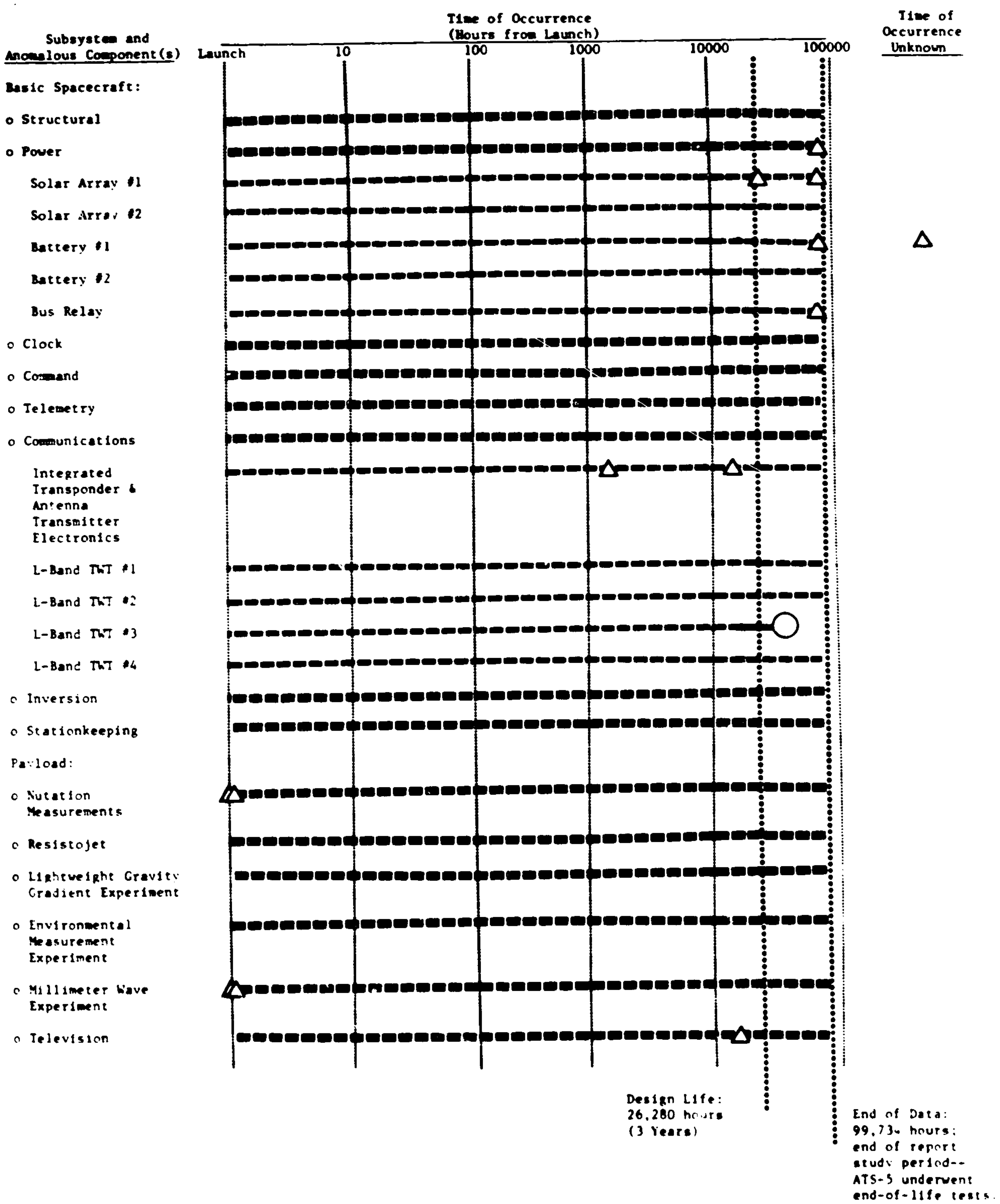
PERFORMANCE SUMMARY FOR ATS-5



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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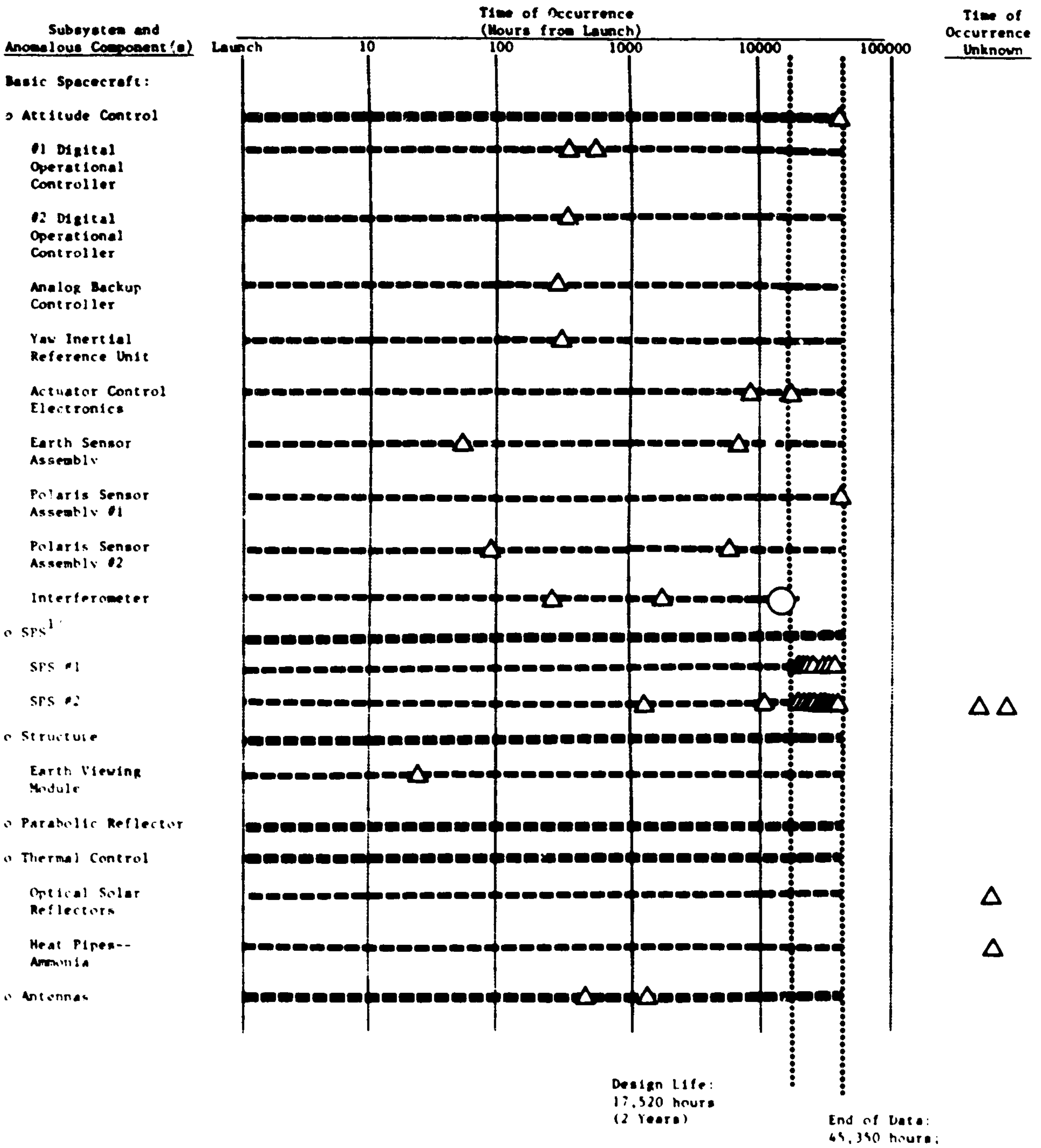
PERFORMANCE SUMMARY FOR ATS-6



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1 SPS = Spacecraft Propulsion Subsystem.

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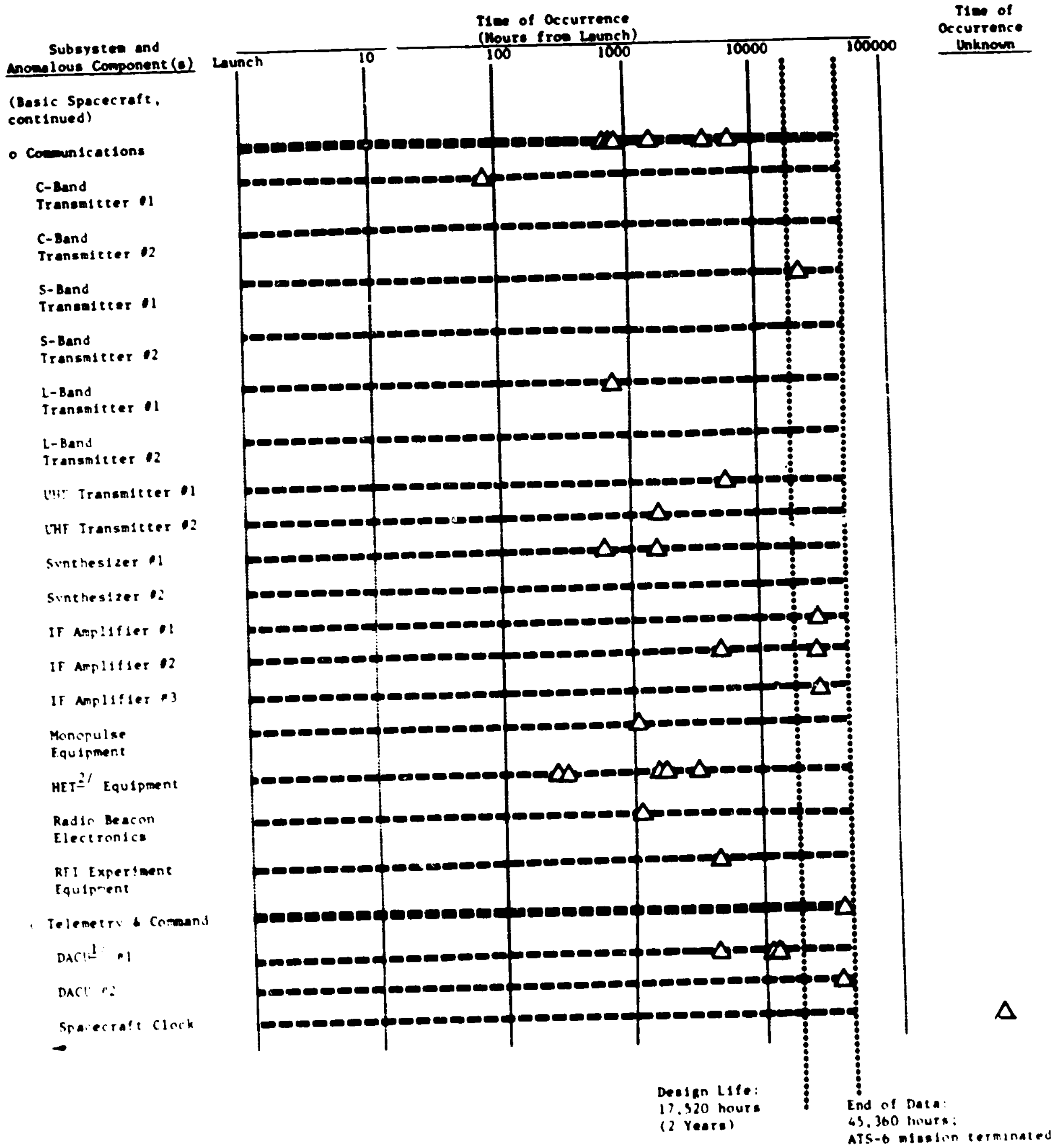
PERFORMANCE SUMMARY FOR ATS-6
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ DACU = Data Acquisition and Control Unit.

2/ HET = High Energy Telescope

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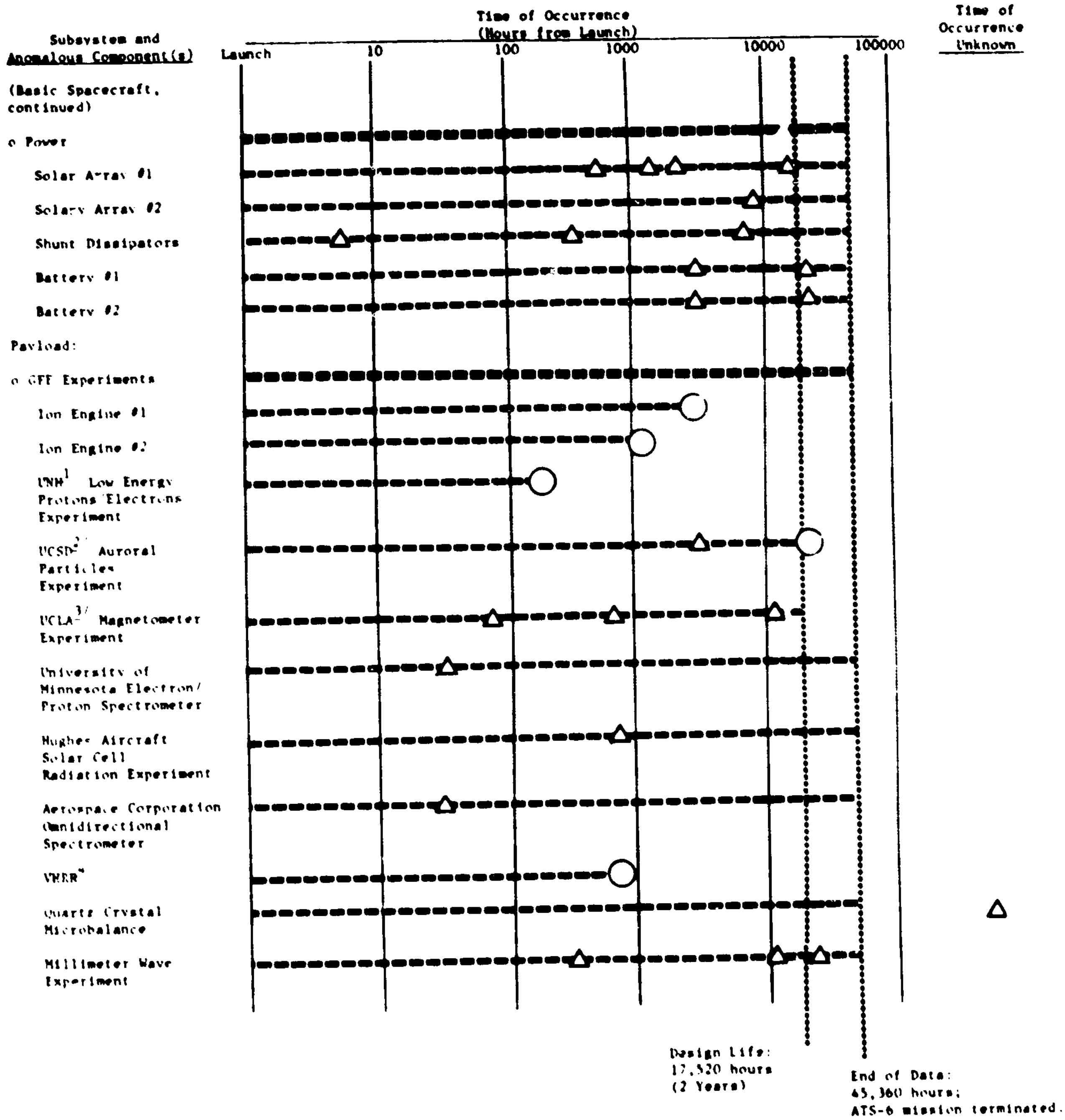
PERFORMANCE SUMMARY FOR ATS-6
(Concluded)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ UNH = University of New Hampshire.
2/ UCSD = University of California, San Diego.
3/ UCLA = University of California, Los Angeles.
4/ VHRR = Very High Resolution Radiometer.

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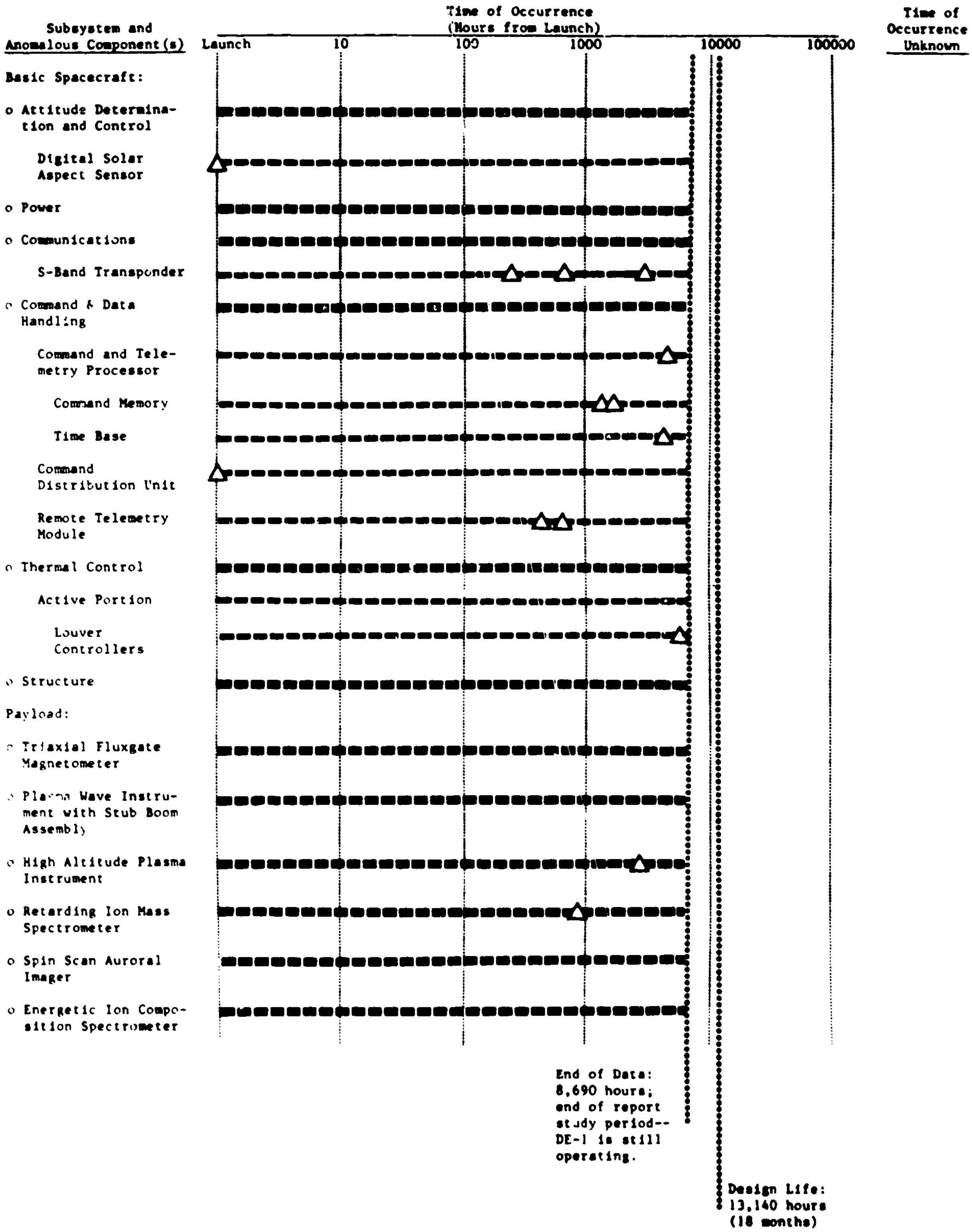
PERFORMANCE SUMMARY FOR DE-1



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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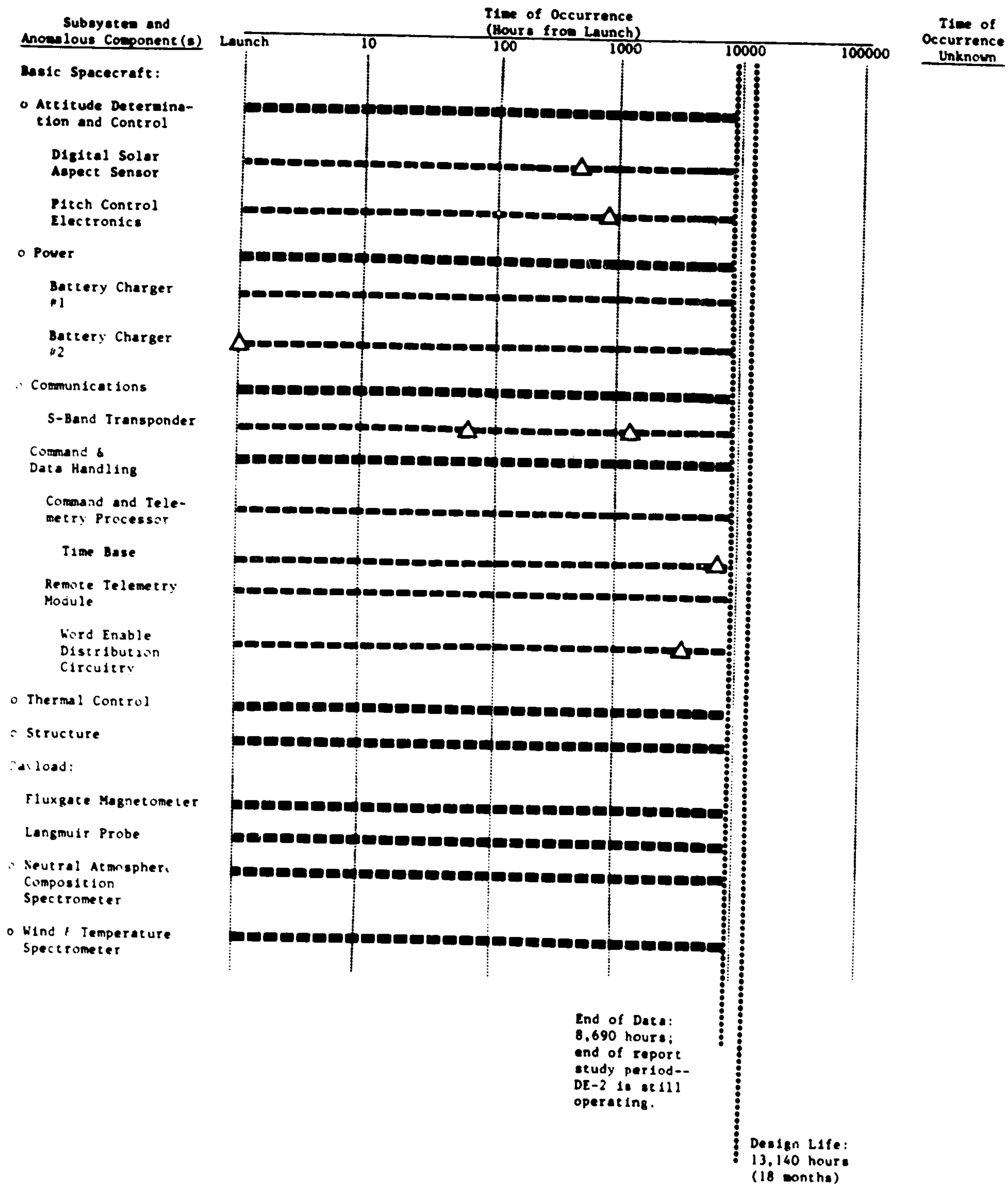
PERFORMANCE SUMMARY FOR DE-2



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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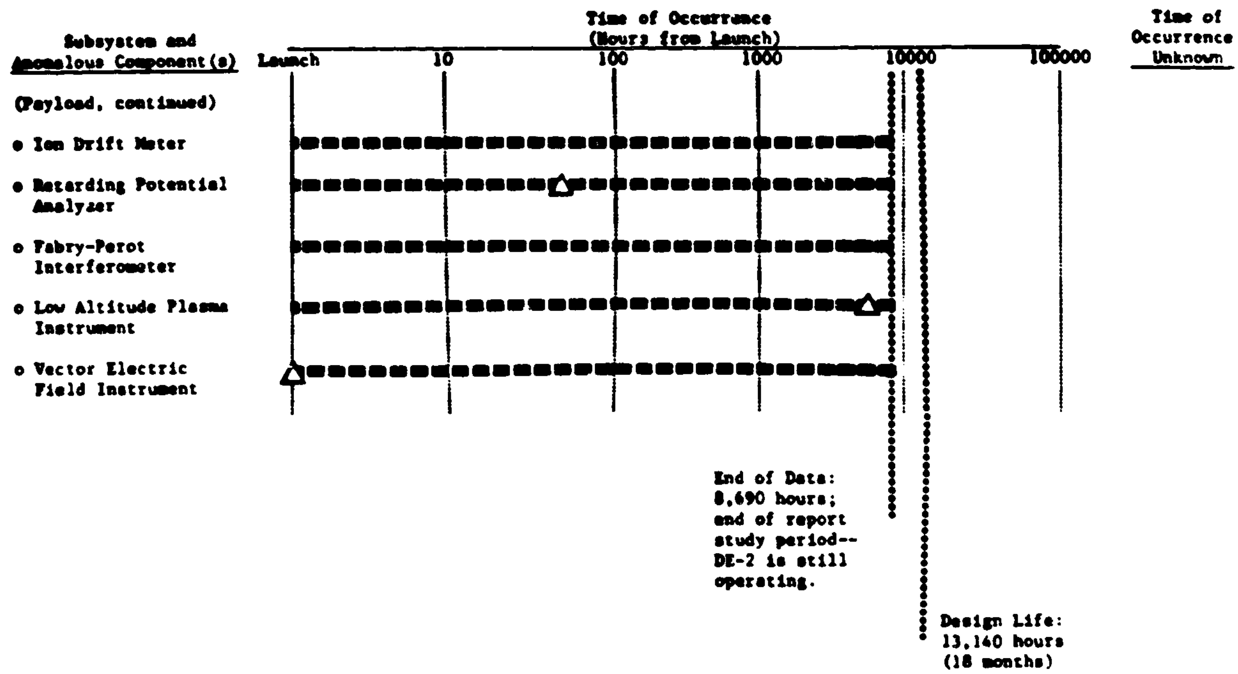
PERFORMANCE SUMMARY FOR DE-2
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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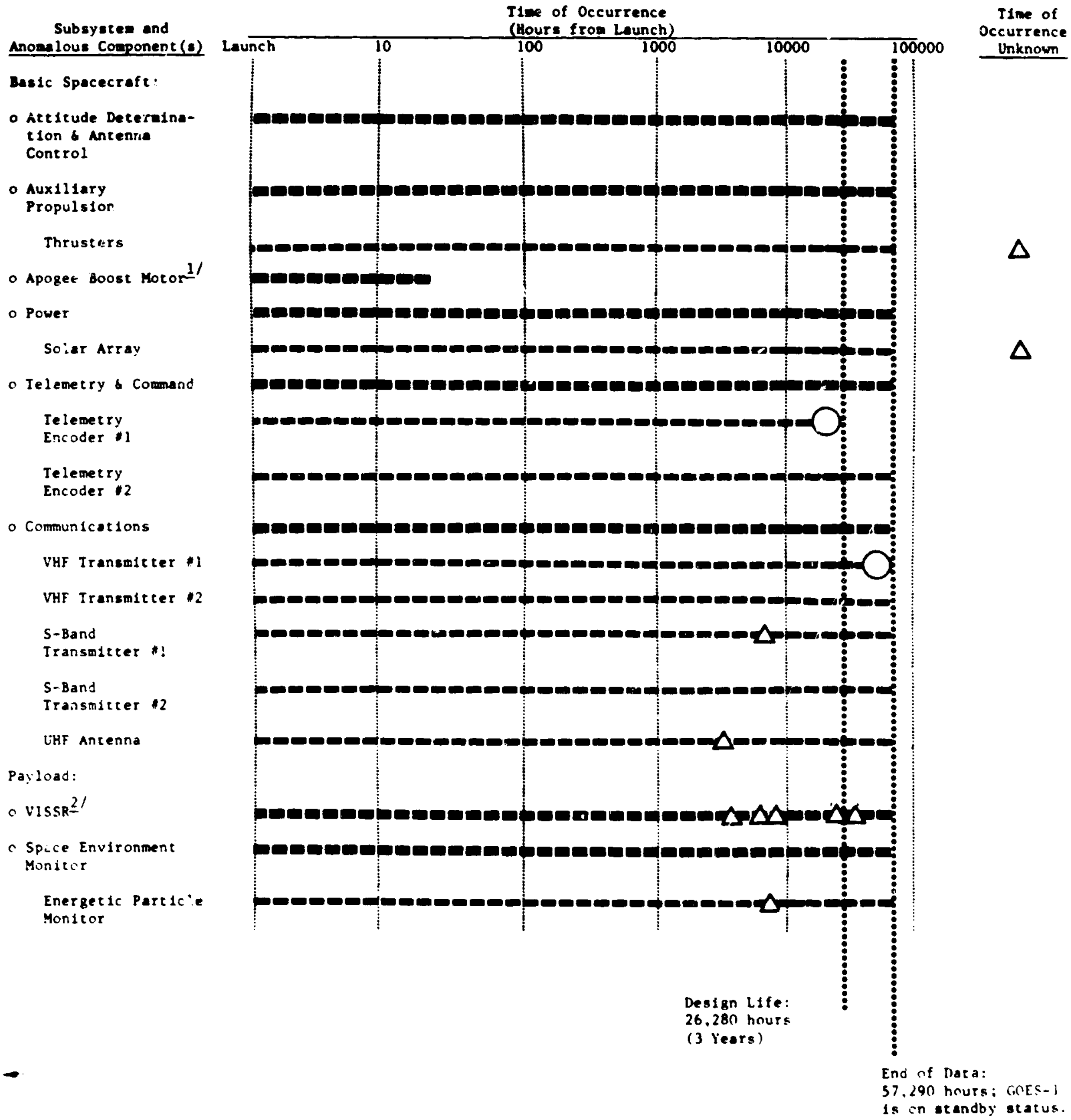
PERFORMANCE SUMMARY FOR GOES-1



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours

2/ VISSR = Visible Infrared Spin Scan Radiometer.

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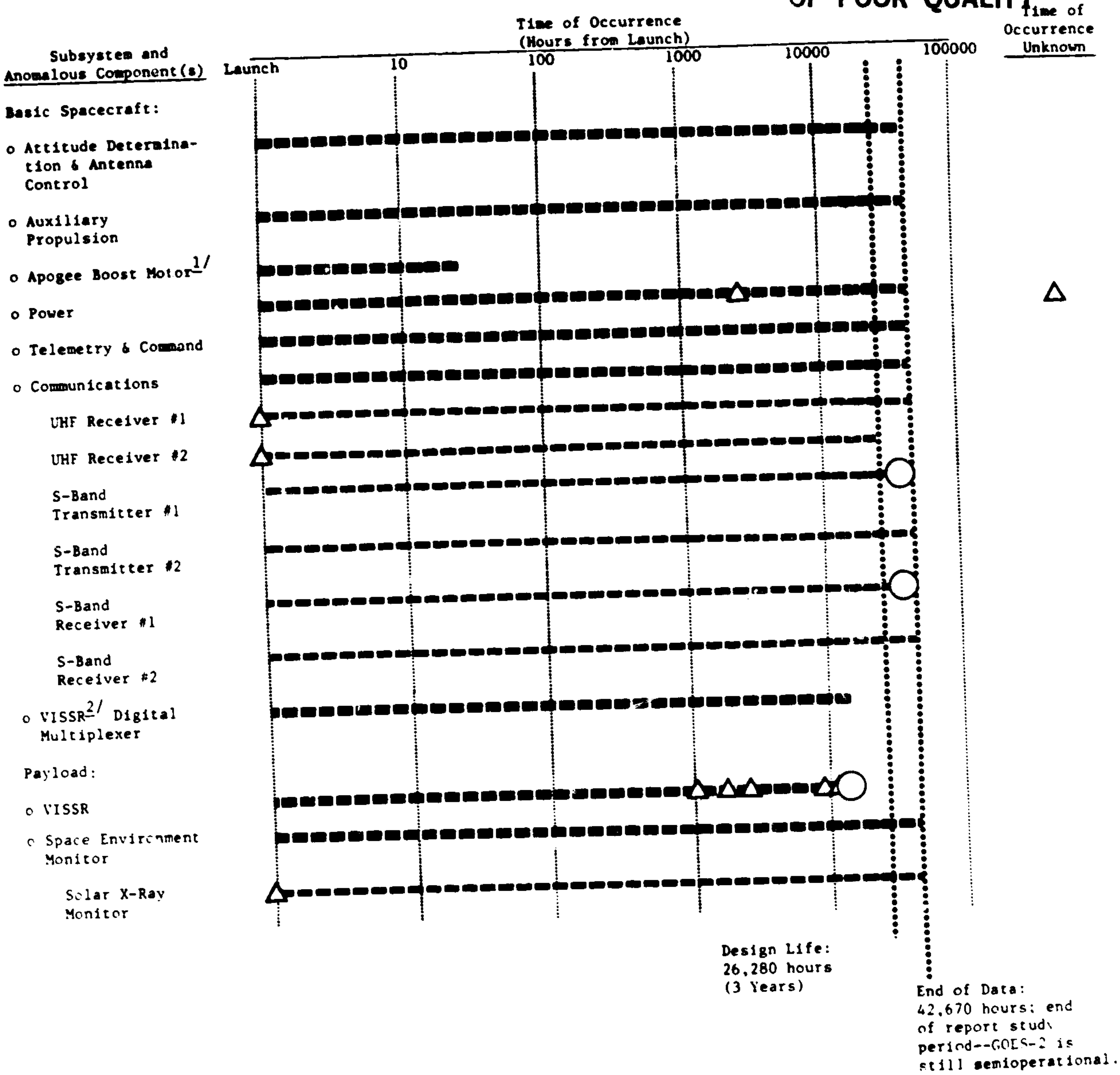
PERFORMANCE SUMMARY FOR GOES-2



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.
2/ VISSR = Visible Infrared Spin Scan Radiometer

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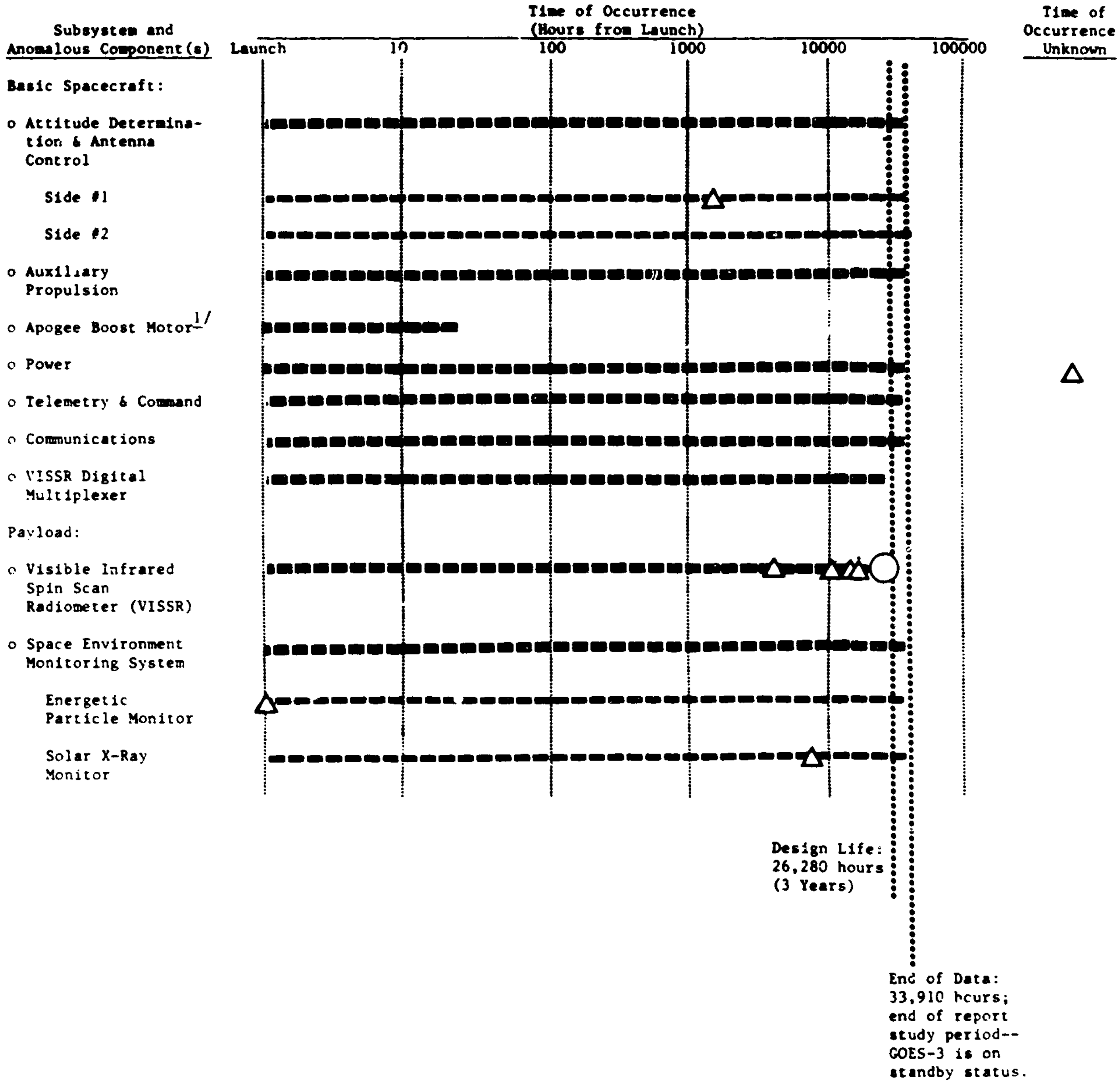
PERFORMANCE SUMMARY FOR GOES-3



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.

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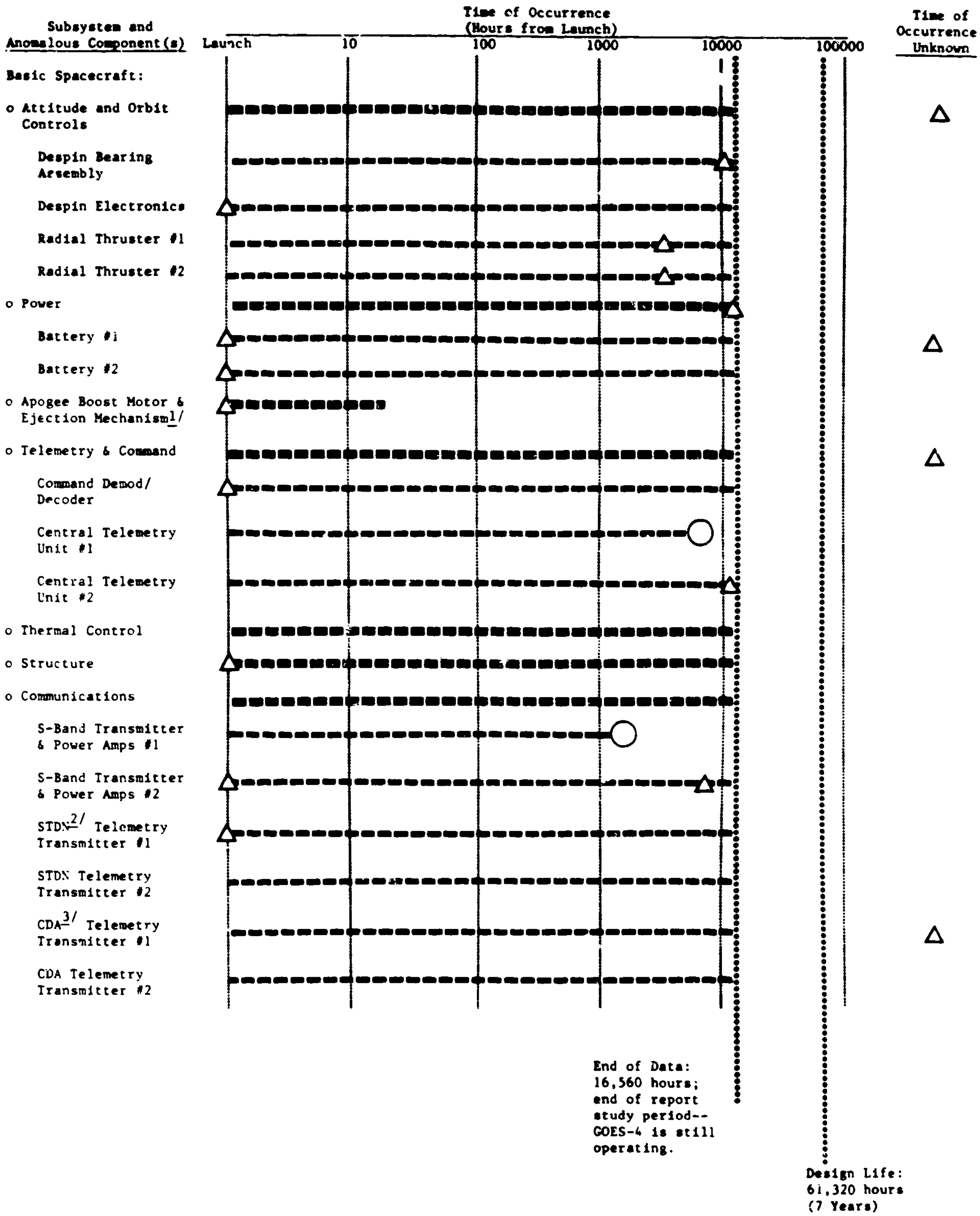
PERFORMANCE SUMMARY FOR GOES-4



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor and ejection mechanism is a one-shot device and has a normal lifetime of 24 hours.
2/ STDN = Spaceflight Tracking and Data Network.
3/ CDA = Command and Data Acquisition.

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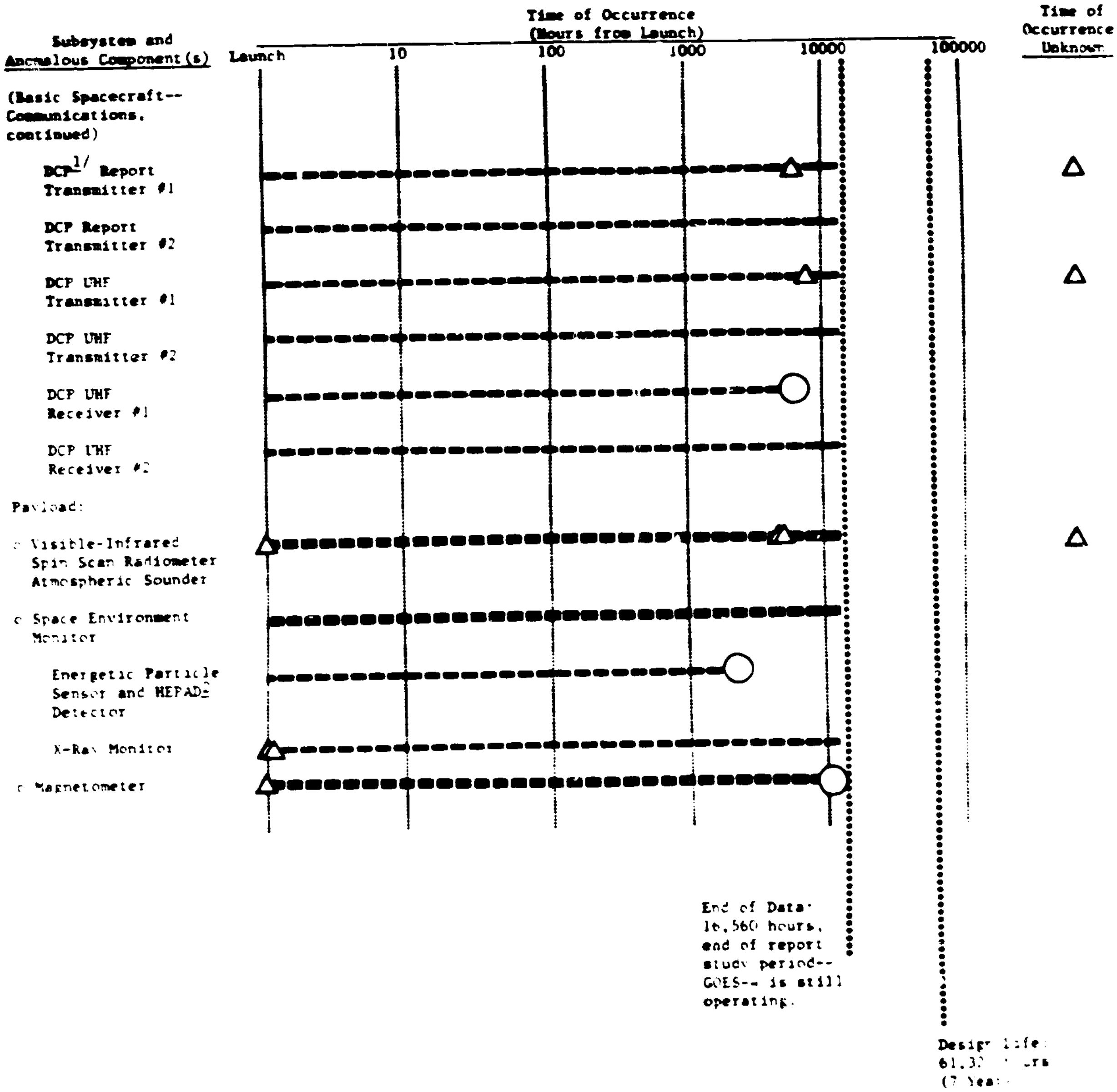
PERFORMANCE SUMMARY FOR GOES-4
(Continued)



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ DCP = Data Collection Platform.
2/ HEPAD = High Energy Particle Detector.

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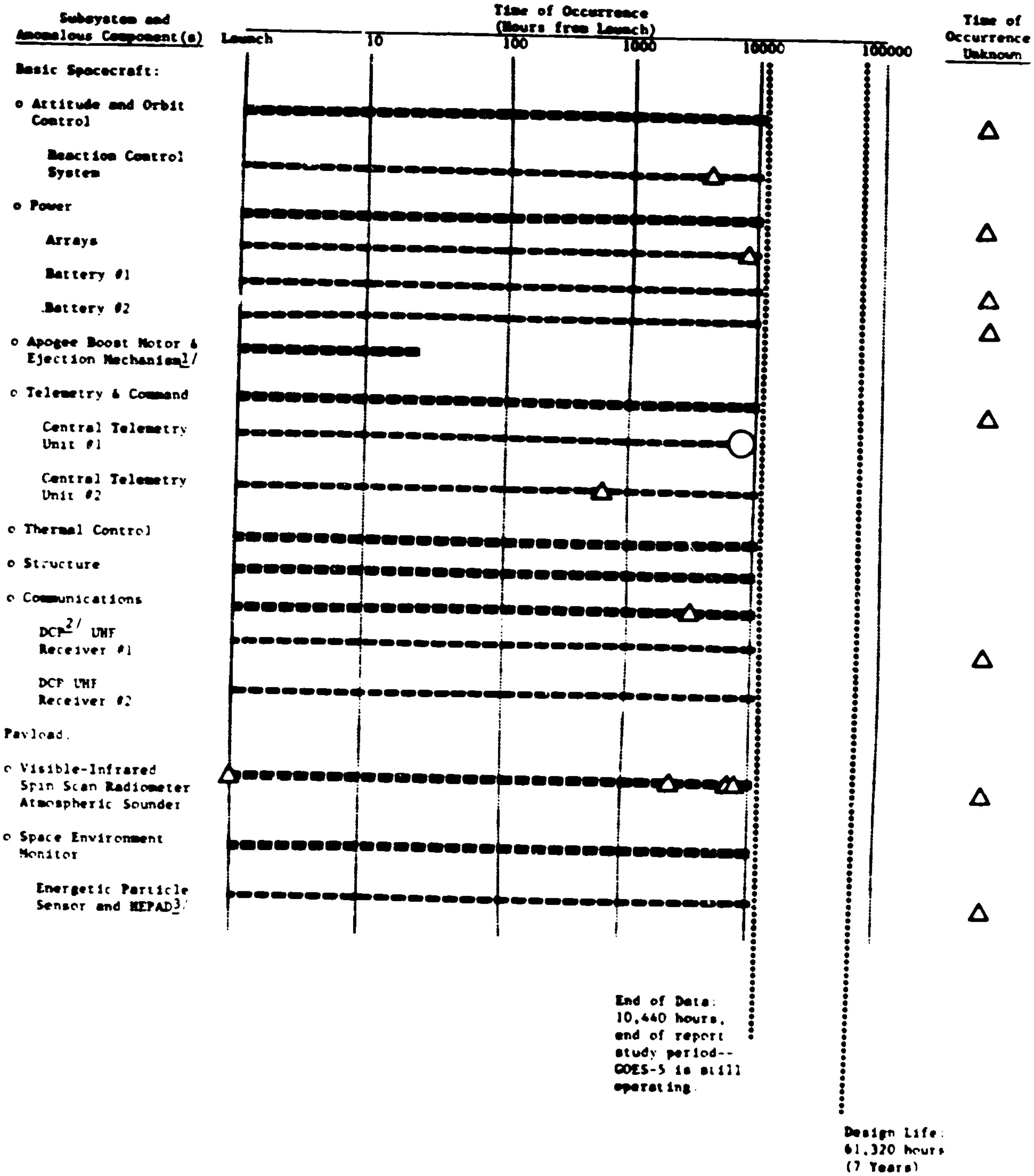
PERFORMANCE SUMMARY FOR GOES-5



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor and ejection mechanism is a none-shot device and has a normal lifetime of 24 hours.
2/ DCP = Data Collection Platform.
3/ HEPAD = High Energy Particle Detector.

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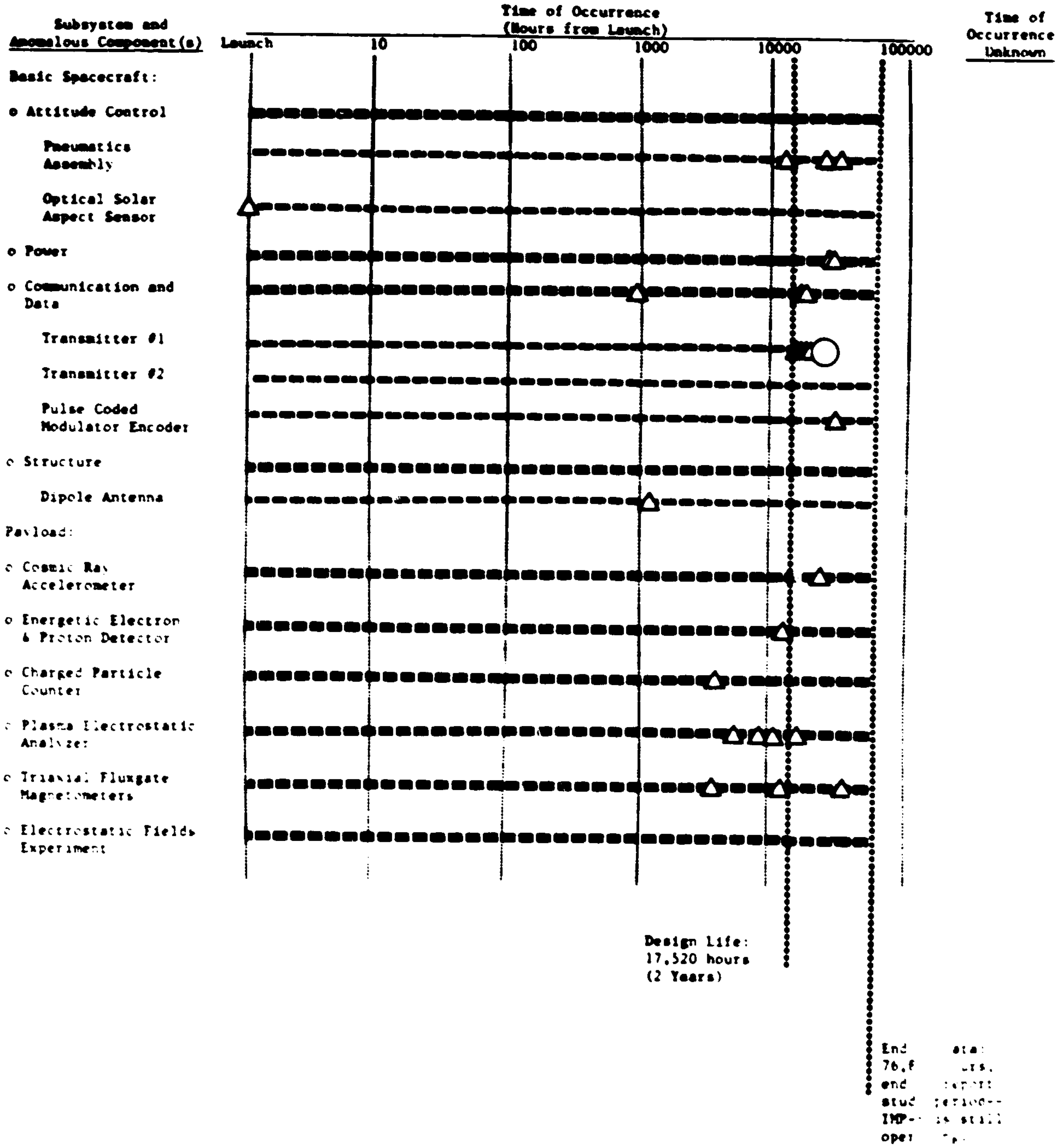
PERFORMANCE SUMMARY FOR IMP-8



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and or component unusable.

△ indicates that this anomaly is not a failure.

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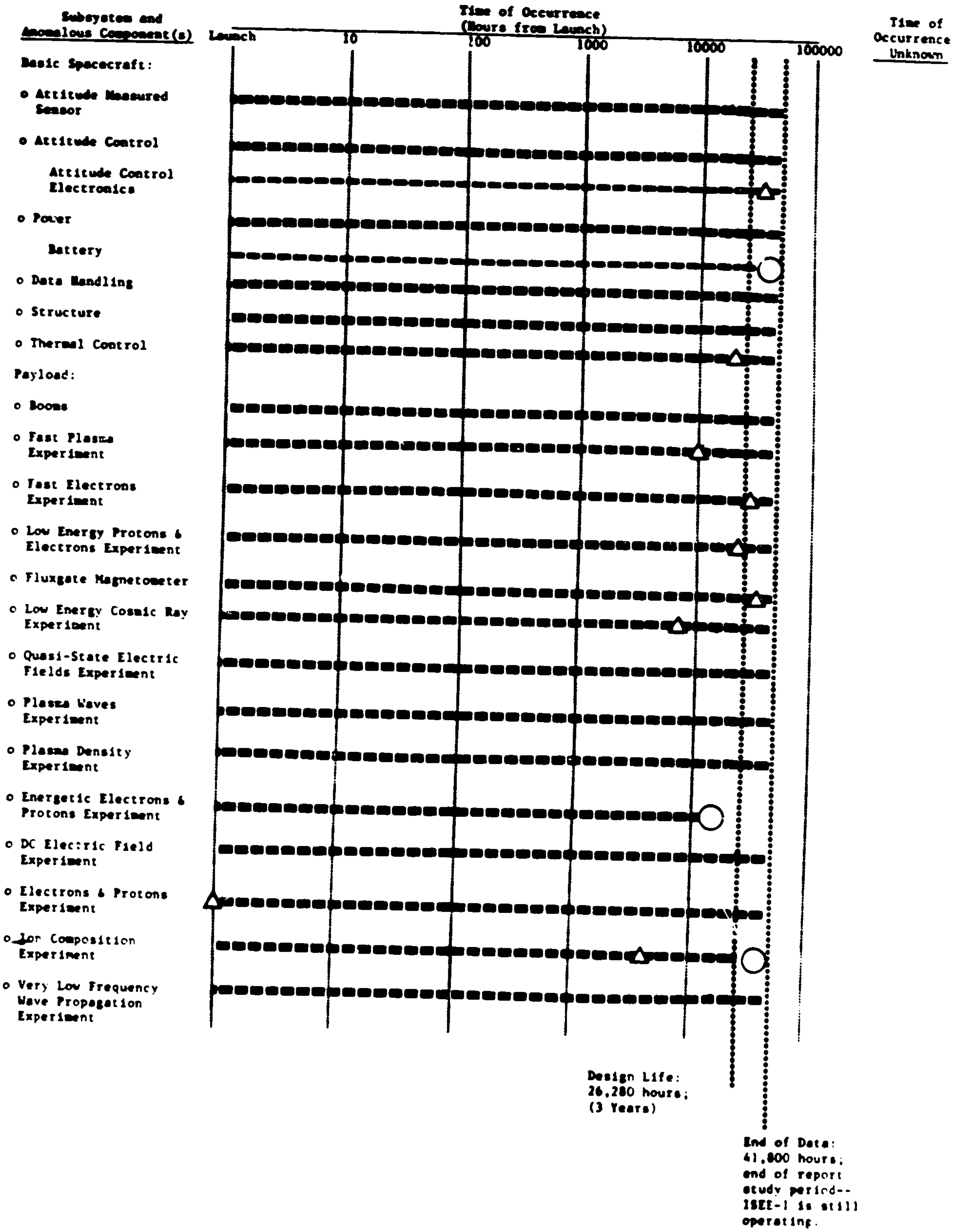
PERFORMANCE SUMMARY FOR ISEE-1



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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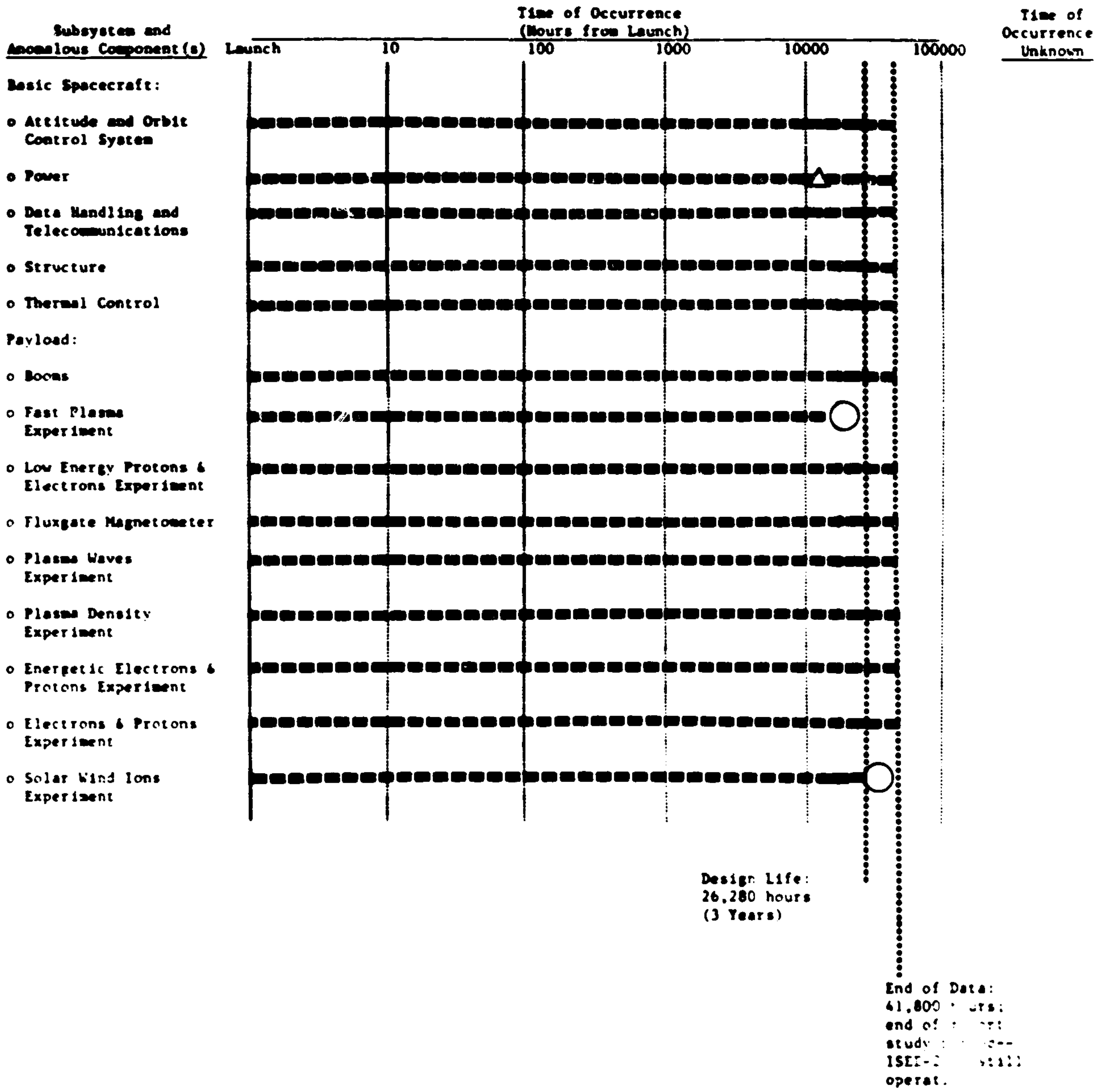
PERFORMANCE SUMMARY FOR ISEE-2



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the s   ster and or component unusable.

△ indicates that this anomaly is not a failure.

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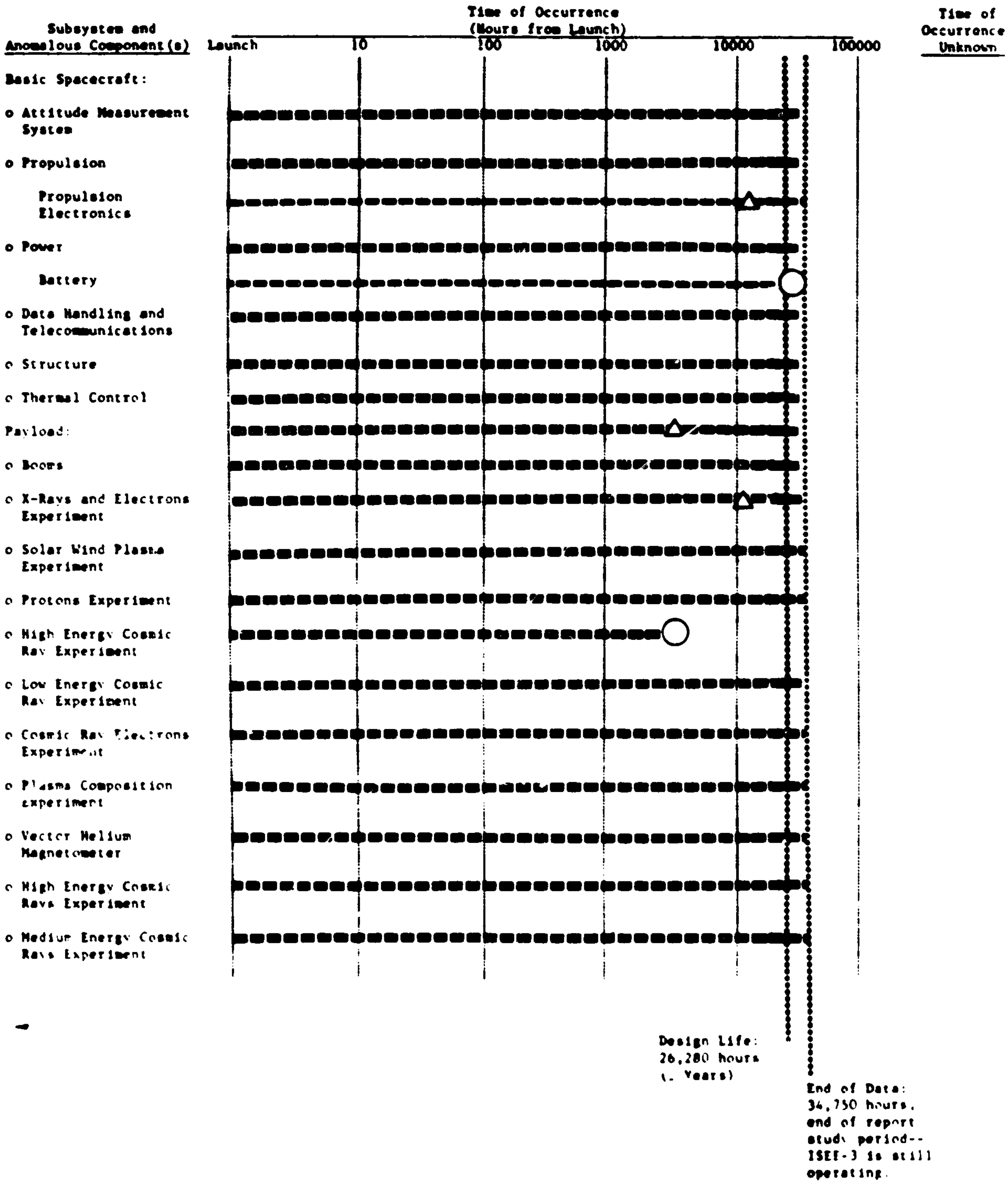
PERFORMANCE SUMMARY FOR ISEE-3



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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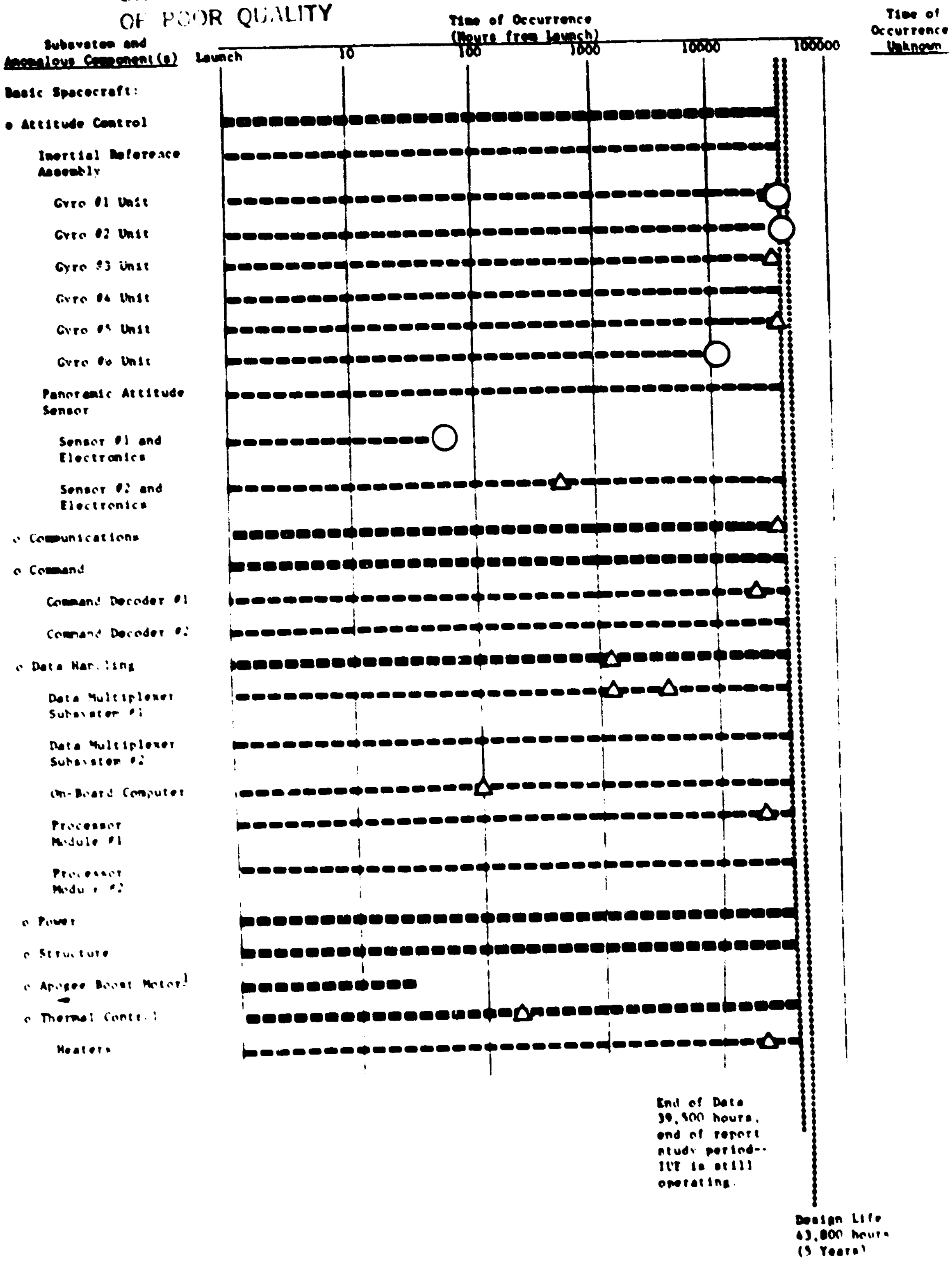
PERFORMANCE SUMMARY FOR IUE



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and or component unusable

△ indicates that this anomaly is not a failure

1 The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours

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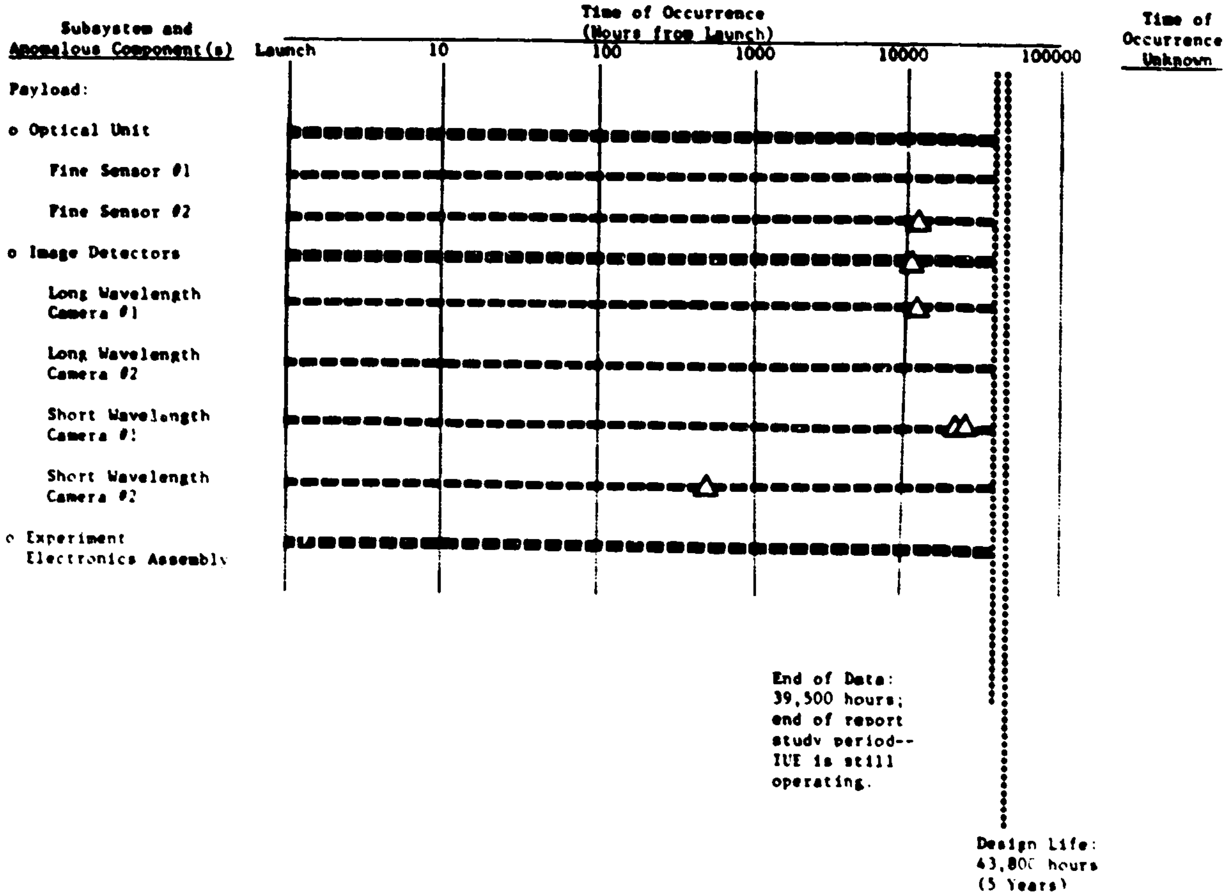
PERFORMANCE SUMMARY FOR IUE
(Continued)



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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and or component unusable.

△ indicates that this anomaly is not a failure.

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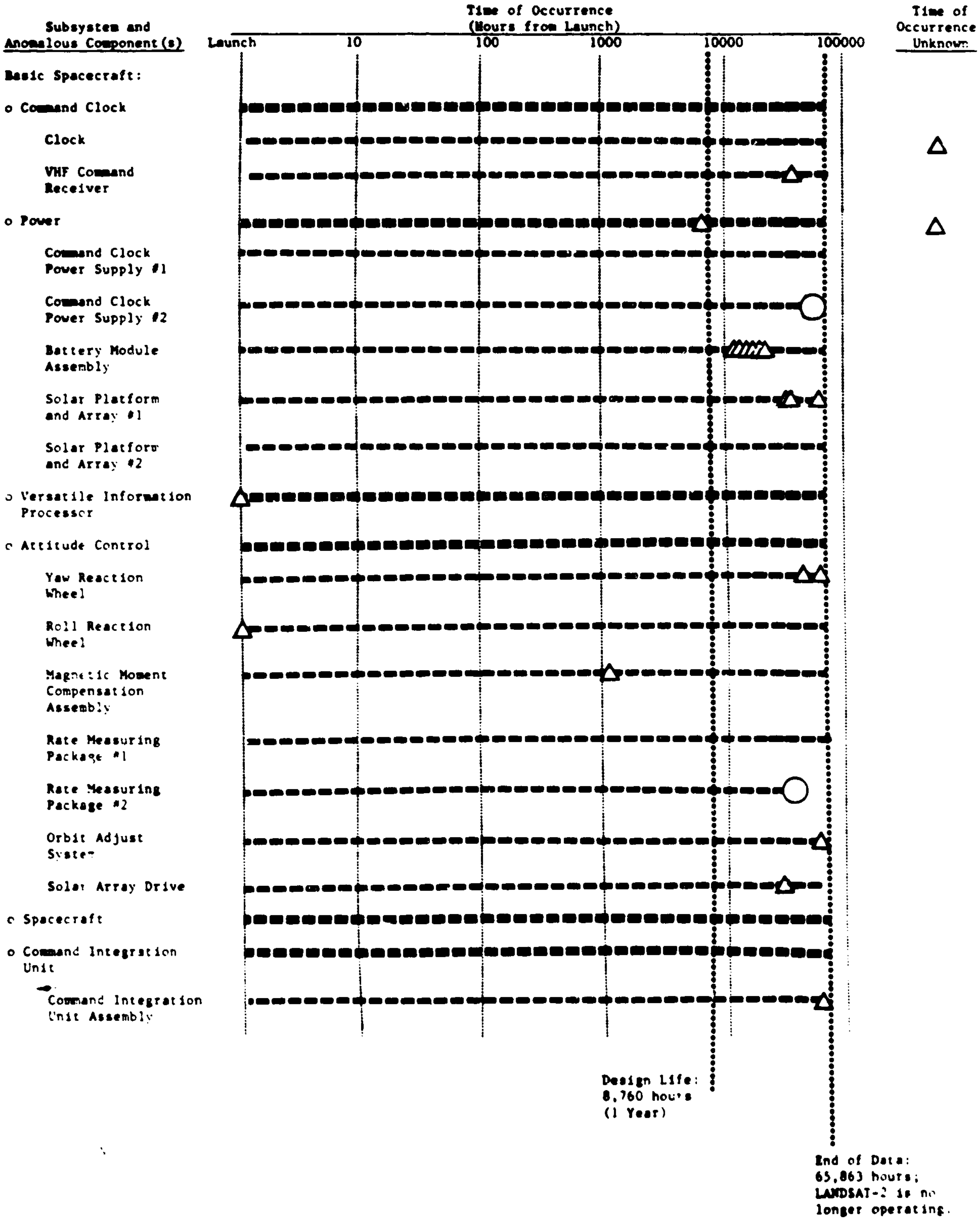
PERFORMANCE SUMMARY FOR LANDSAT-2



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and or component unusable.

△ indicates that this anomaly is <u>not</u> a failure.

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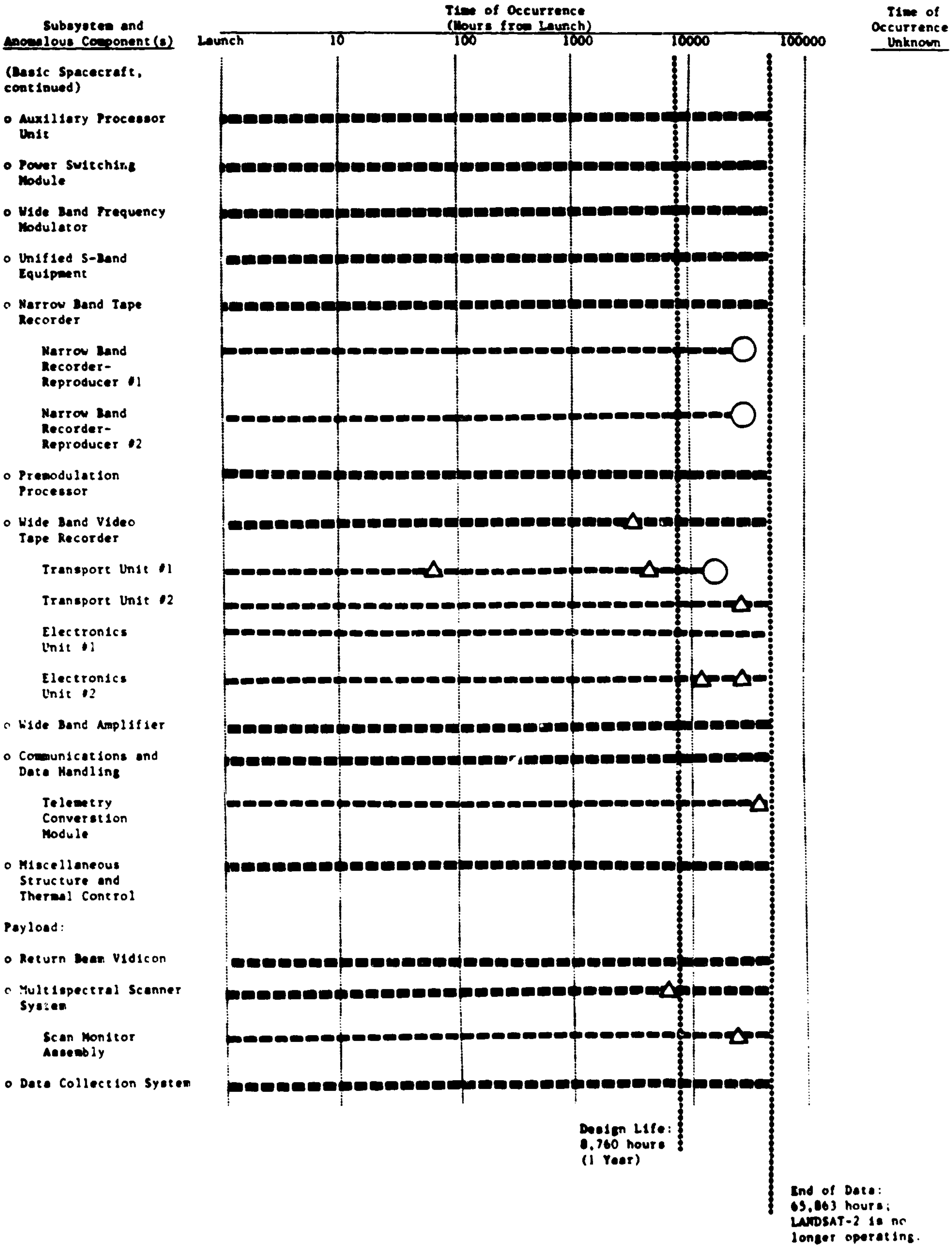
PERFORMANCE SUMMARY FOR LANDSAT-2
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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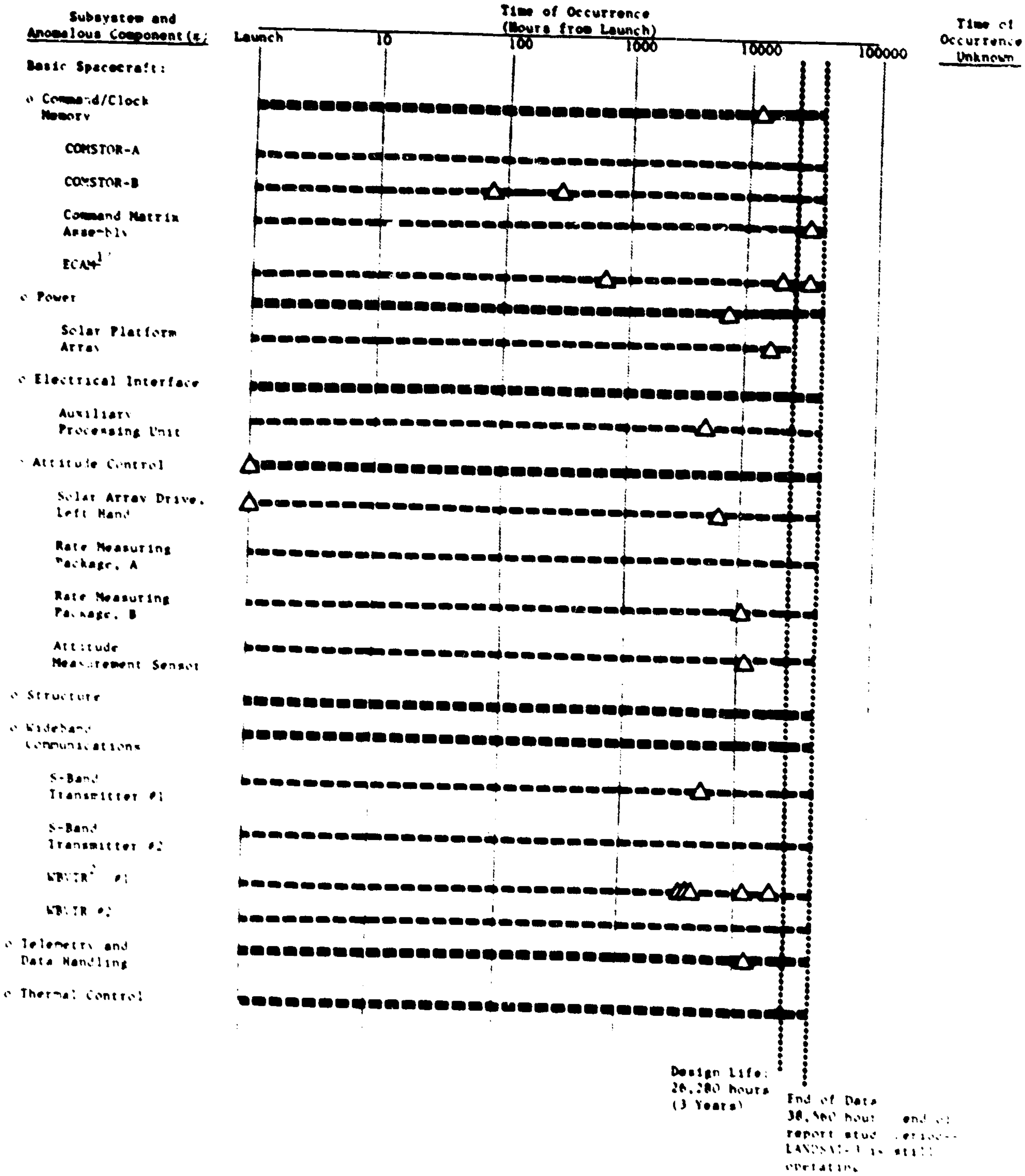
PERFORMANCE SUMMARY FOR LANDSAT-3



Legend

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ ECAM = ERTS Command Auxiliary Memory

2/ WBVTR = Wide Band Video Tape Recorder

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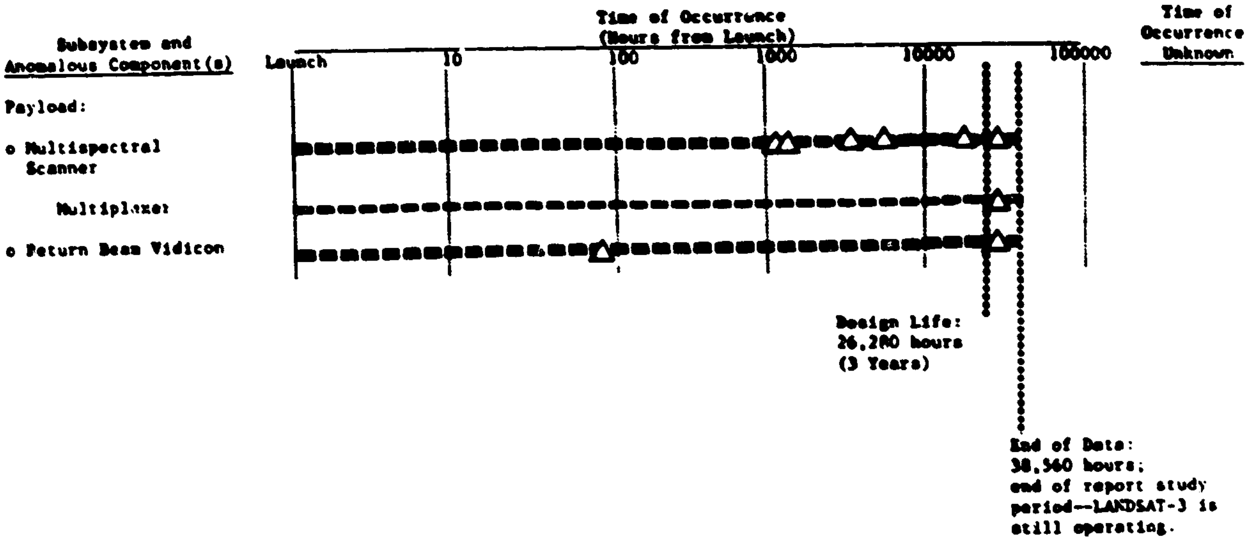
PERFORMANCE SUMMARY FOR LANDSAT-3
(Continued)



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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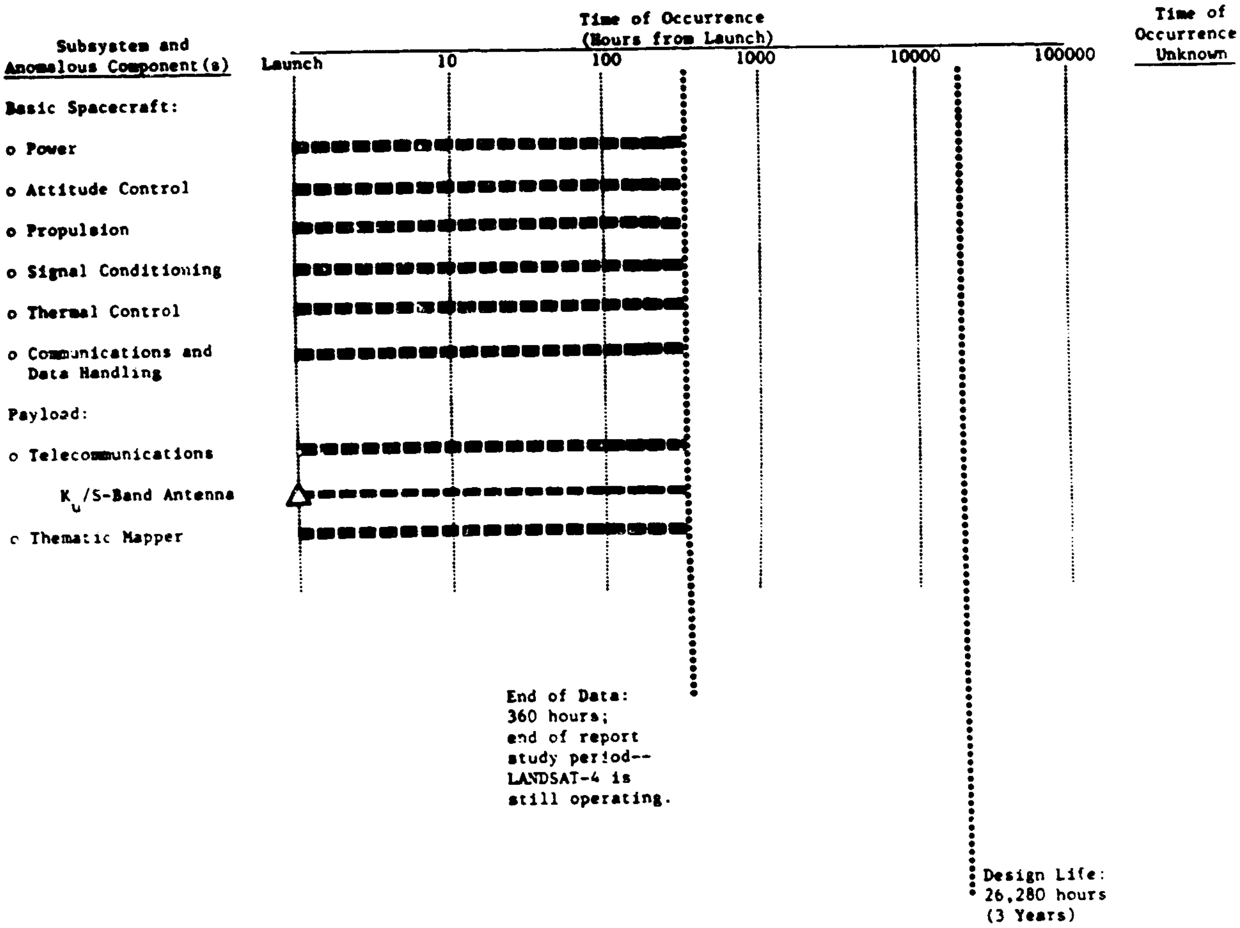
PERFORMANCE SUMMARY FOR LANDSAT-4



Legend:

○ indicates that this anomaly is a failure, where failure is defines as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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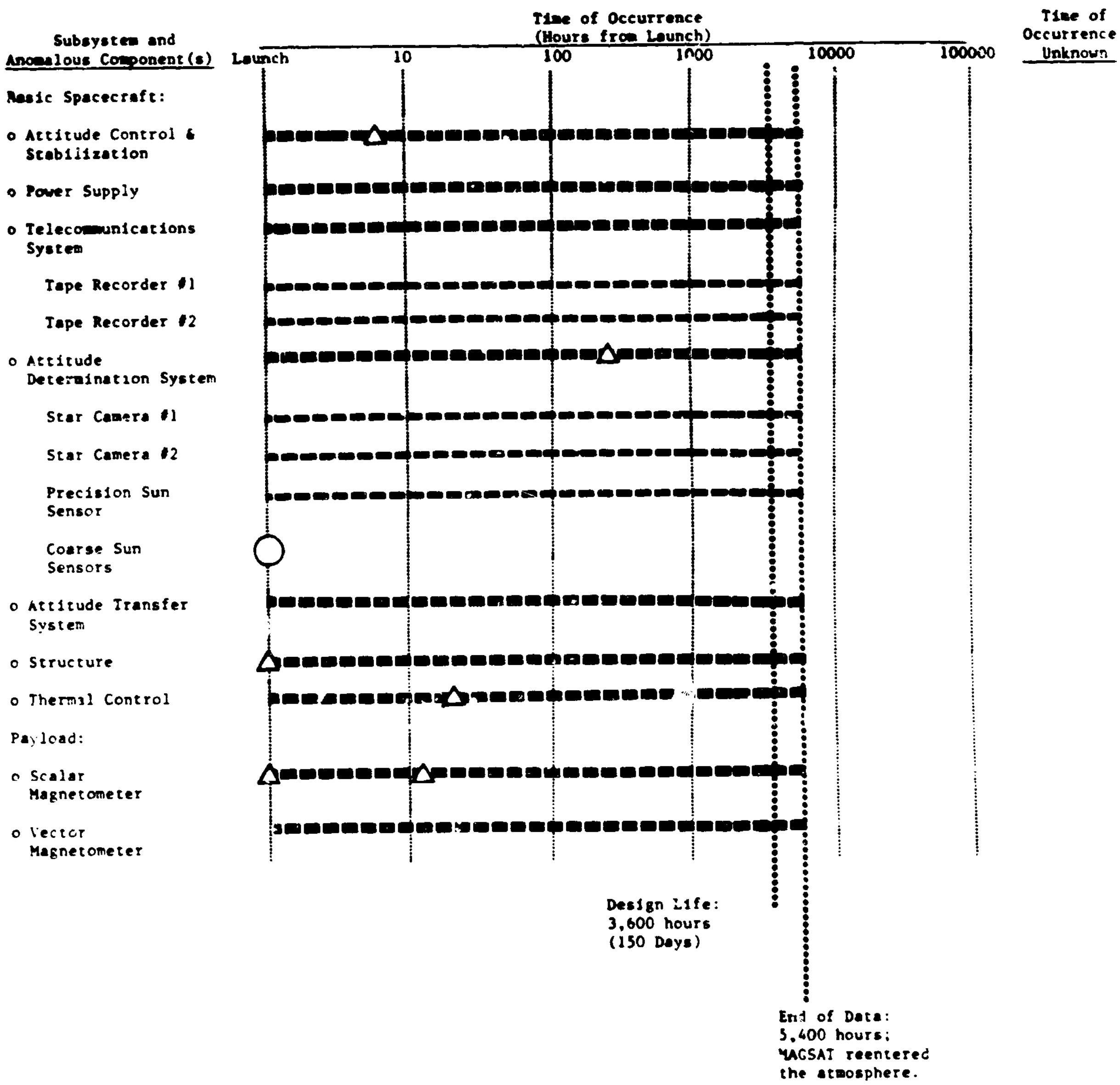
PERFORMANCE SUMMARY FOR MAGSAT



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

PERFORMANCE SUMMARY FOR NIMBUS-4

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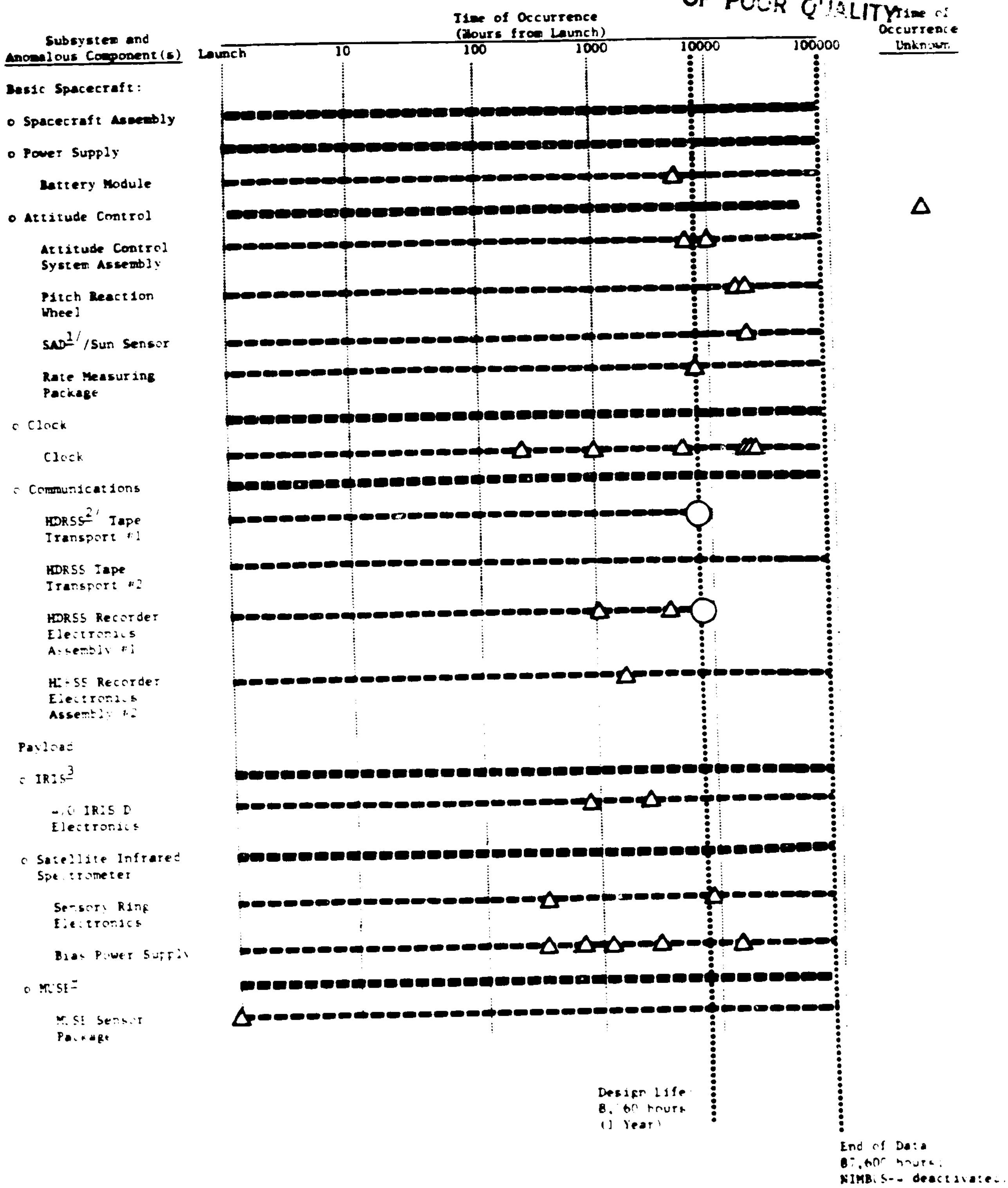

Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable

△ indicates that this anomaly is not a failure

1/ SAD = Solar Array Drive
2/ HDRSS = High Data Rate Storage System
3/ IRIS = Infrared Interferometer Spectrometer
4/ MUSE = Monitor Ultraviolet Solar Energy

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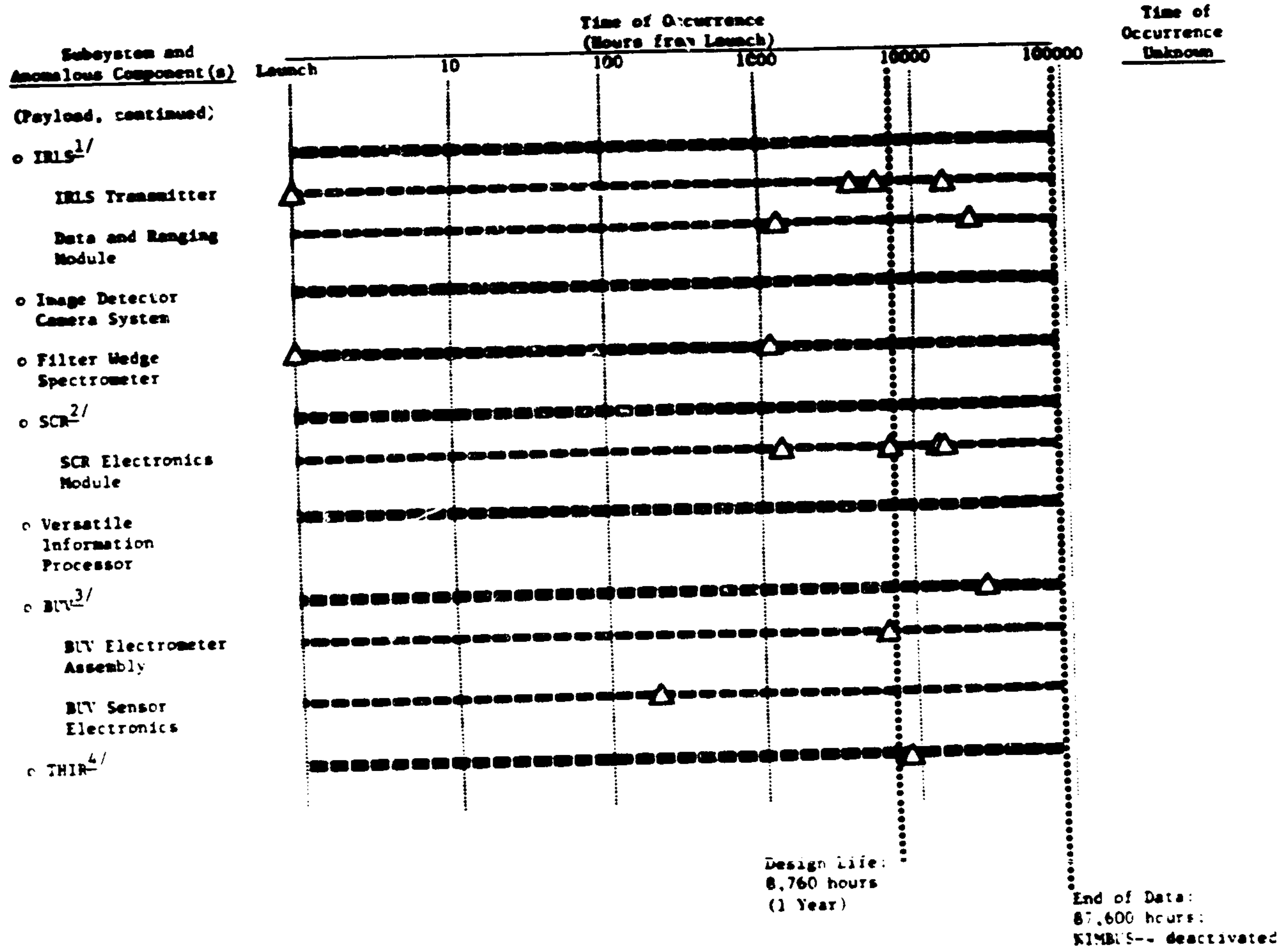
PERFORMANCE SUMMARY FOR NIMBUS-4
(Continued)



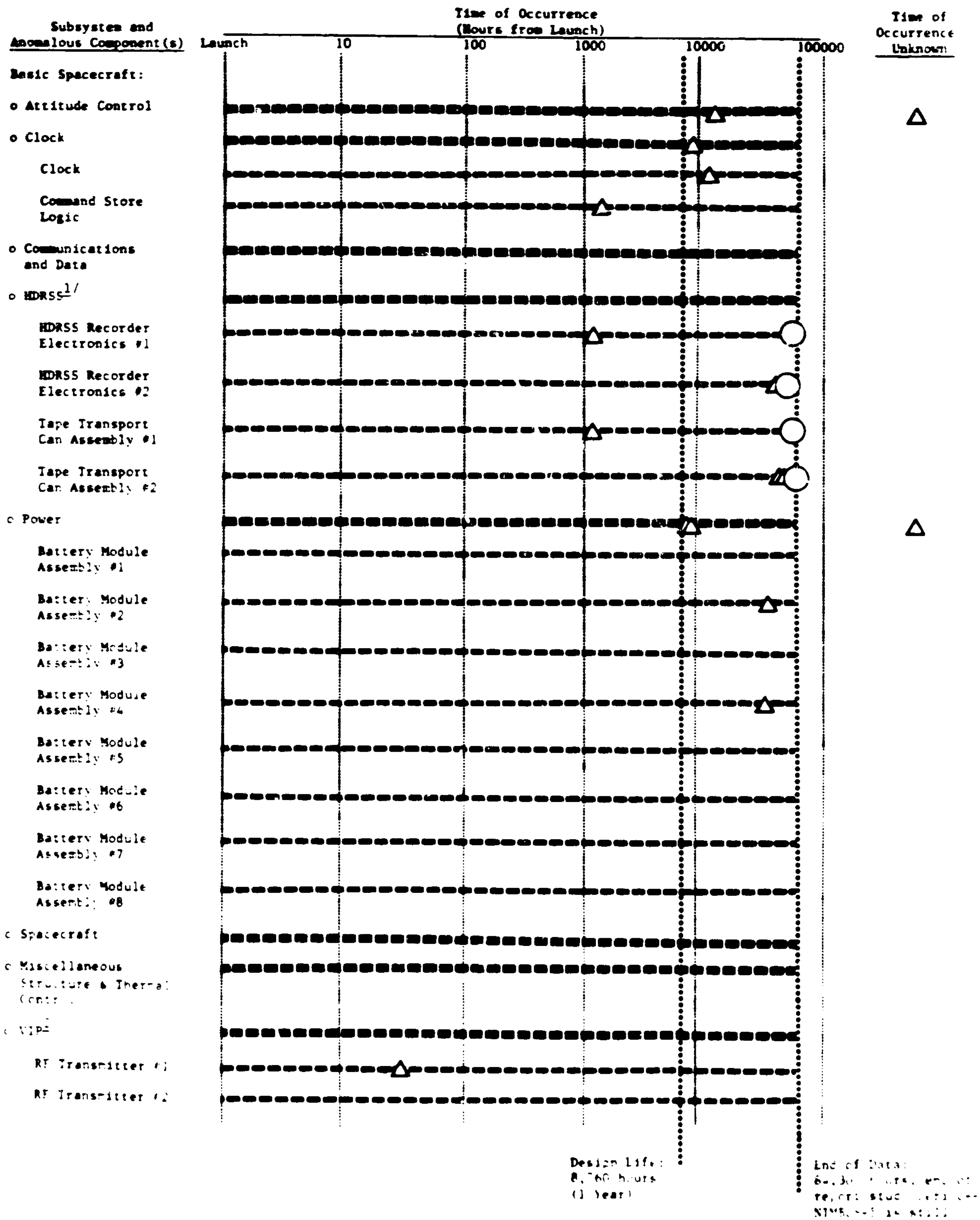
Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ IRLS = Interrogation Recording Location System.
2/ SCR = Selective Chopper Radiometer.
3/ BUV = Backscatter Ultraviolet.
4/ THIR = Temperature/Humidity Infrared Radiometer.

PERFORMANCE SUMMARY FOR NIMBUS-5



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ HDRSS = High Data Rate Storage System

2/ VIP = Versatile Information Processor.

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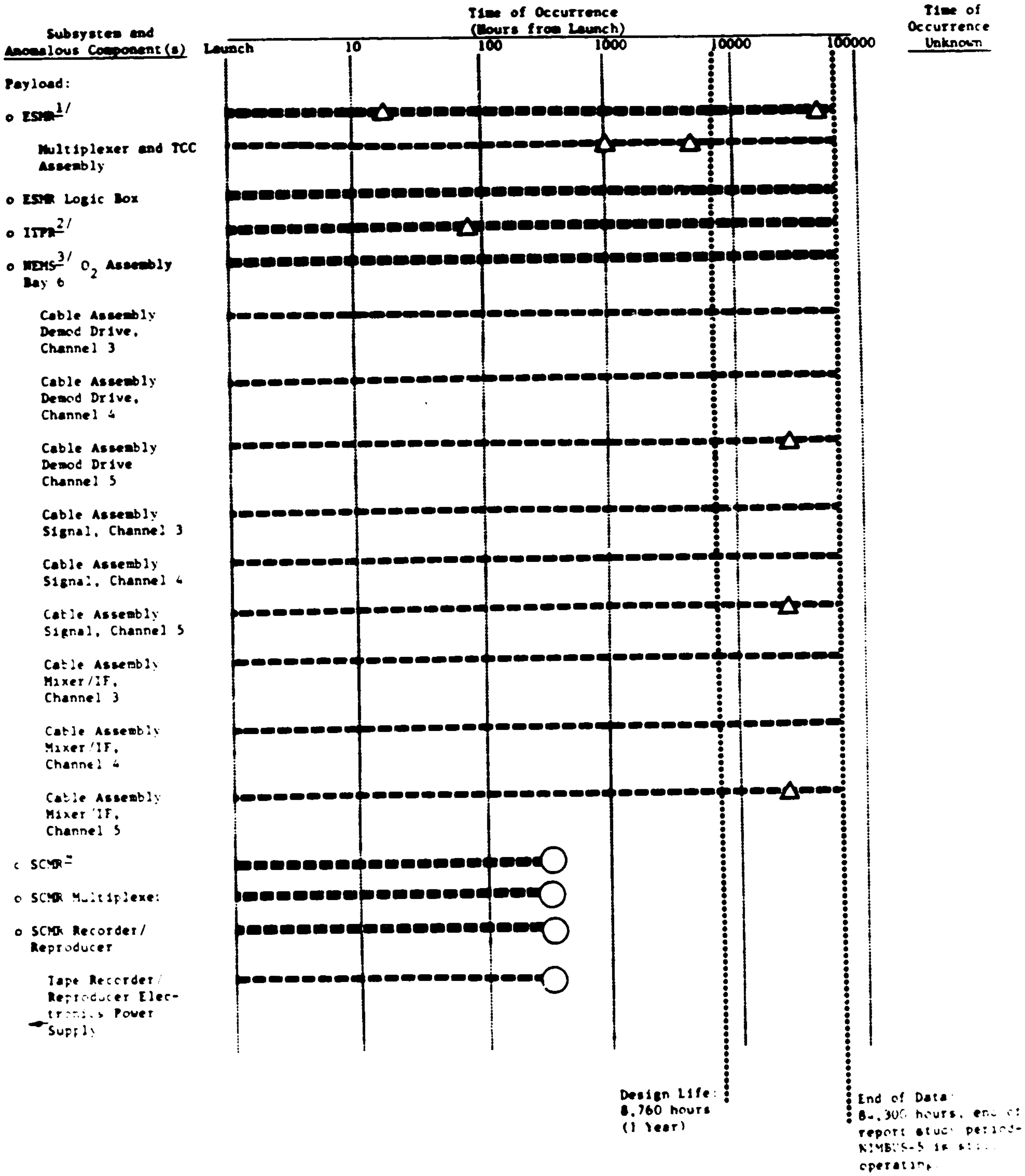
PERFORMANCE SUMMARY FOR NIMBUS-5
(Continued)



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ ESMR = Electrically Scanned Microwave Radiometer
2/ ITPR = Infrared Temperature Profile Radiometer
3/ NEMS = Nimbus-E Microwave Spectrometer
4/ SCMR = Surface Composition Mapping Radiometer

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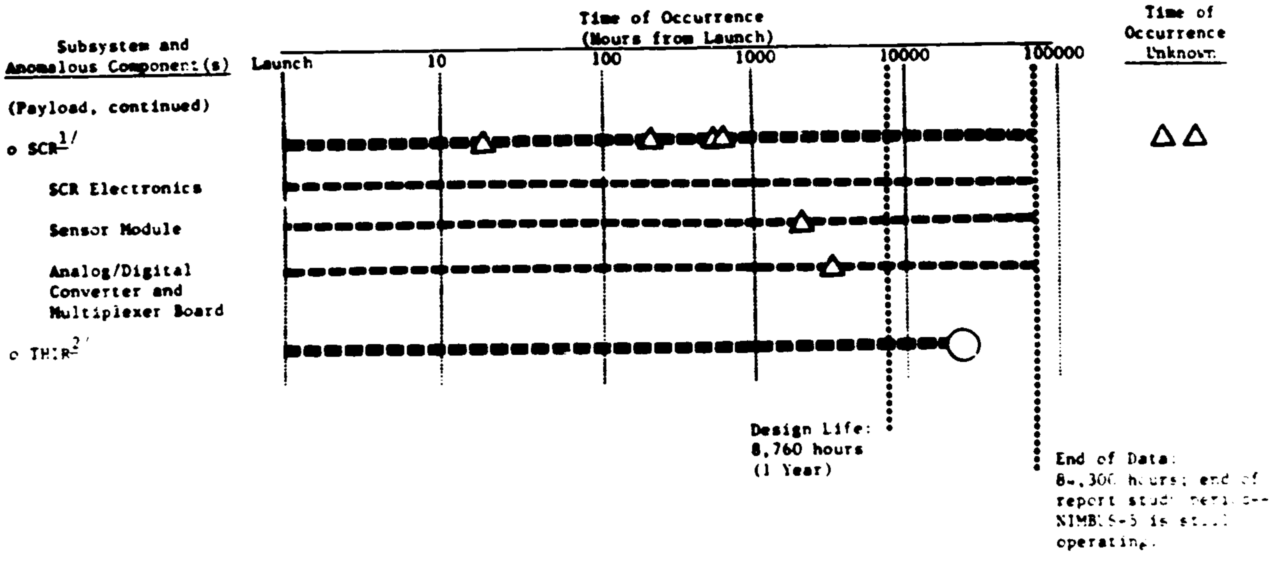
PERFORMANCE SUMMARY FOR NIMBUS-5
(Concluded)



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ SCR = Selective Chopper Radiometer.
2/ THIR = Temperature Humidity Infrared Radiometer.

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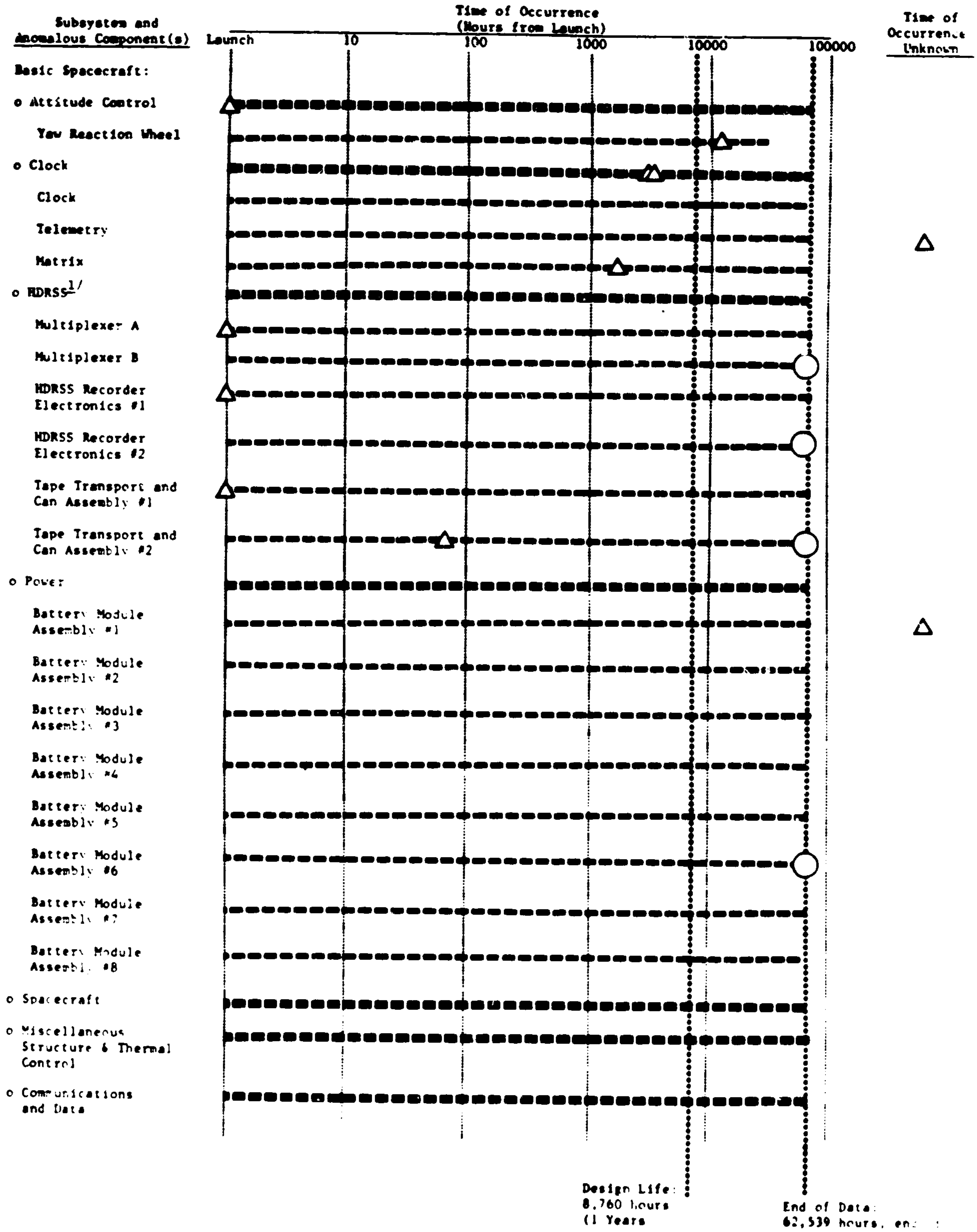
PERFORMANCE SUMMARY FOR NIMBUS-6



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ HDRSS = High Data Rate Storage System

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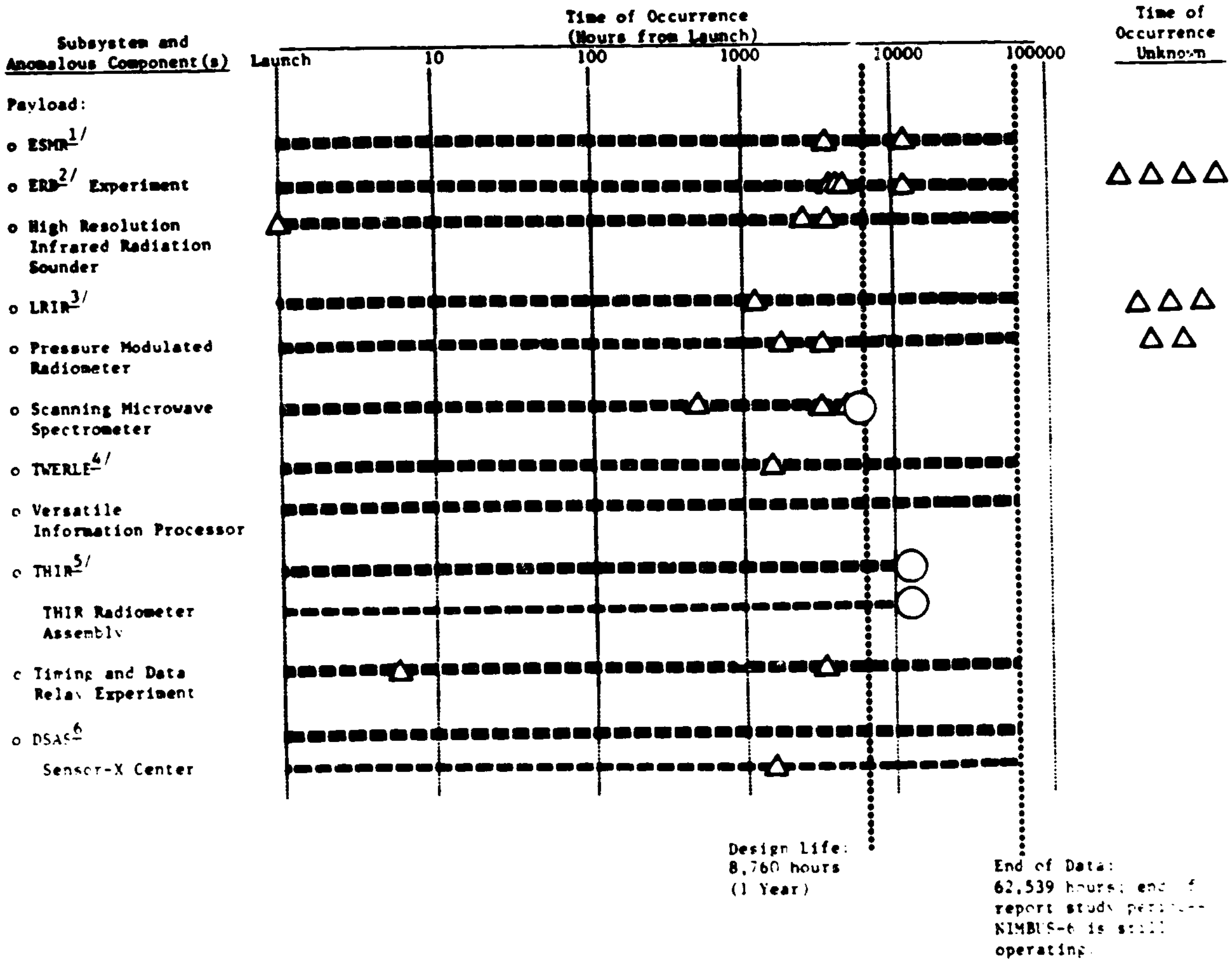
PERFORMANCE SUMMARY FOR NIMBUS-6
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ ESMR = Electrically Scanned Microwave Radiometer.
2/ ERB = Earth Radiation Budget
3/ LRIR = Limb Radiance Inversion Radiometer.
4/ TWERLE = Tropical Wind, Energy, Conservation and Reference Level Experiment.
5/ THIR = Temperature/Humidity Infrared Radiometer.
6/ DSAS = Digital Solar Aspect Sensor.

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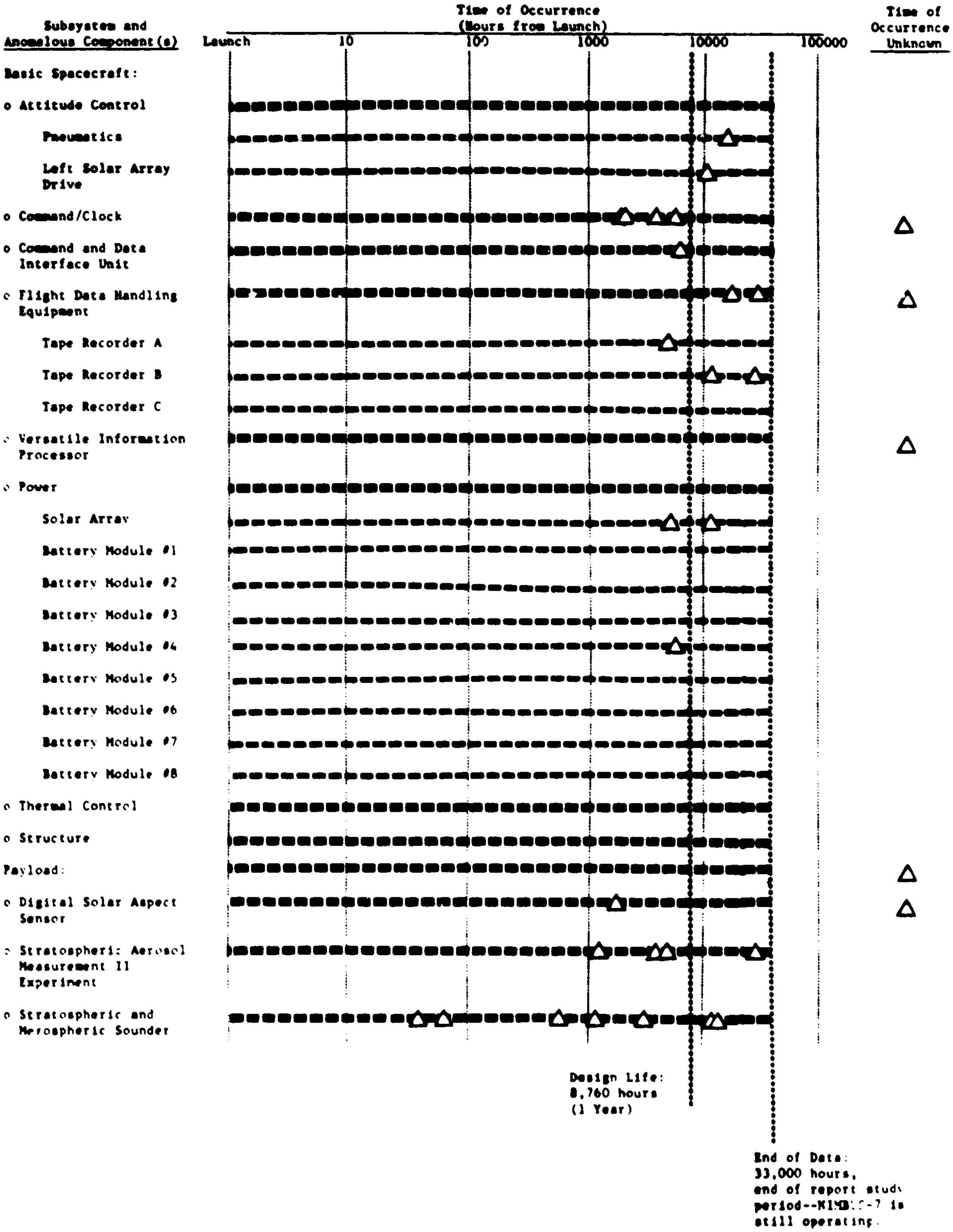
PERFORMANCE SUMMARY FOR NIMBUS-7



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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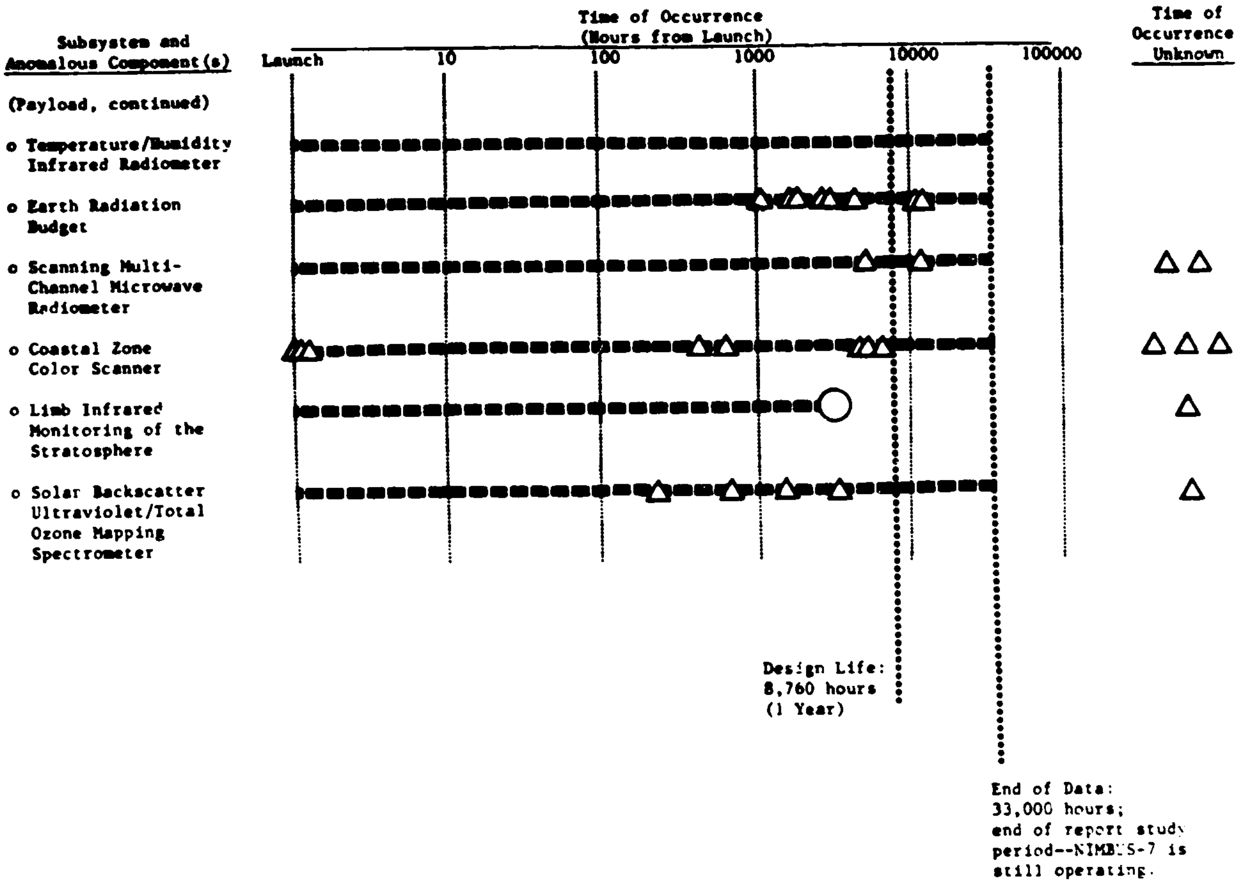
PERFORMANCE SUMMARY FOR NIMBUS-7
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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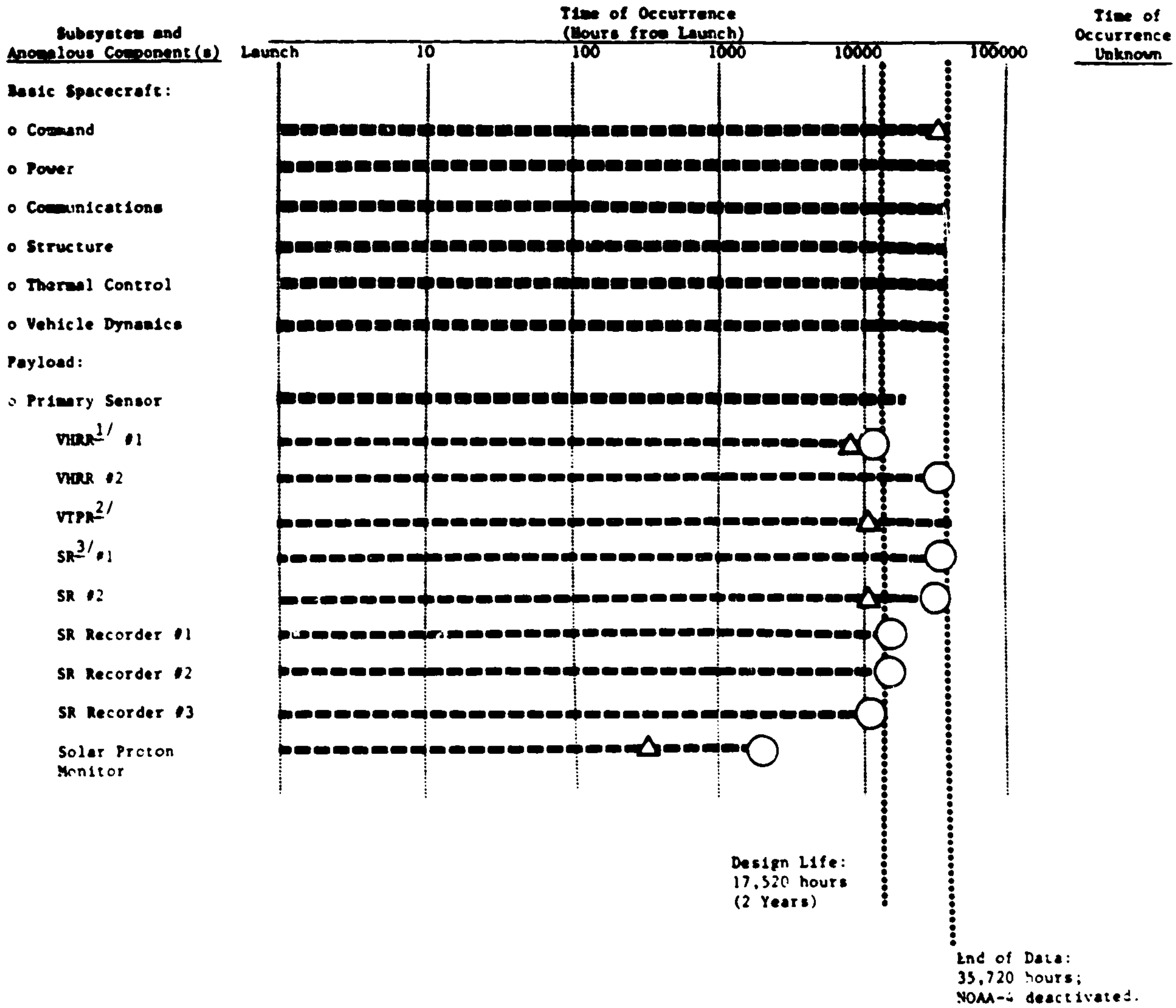
PERFORMANCE SUMMARY FOR NOAA-4



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ VHRR = Very High Resolution Radiometer.
2/ VTPR = Vertical Temperature Profile Radiometer.
3/ SR = Scanning Radiometer.

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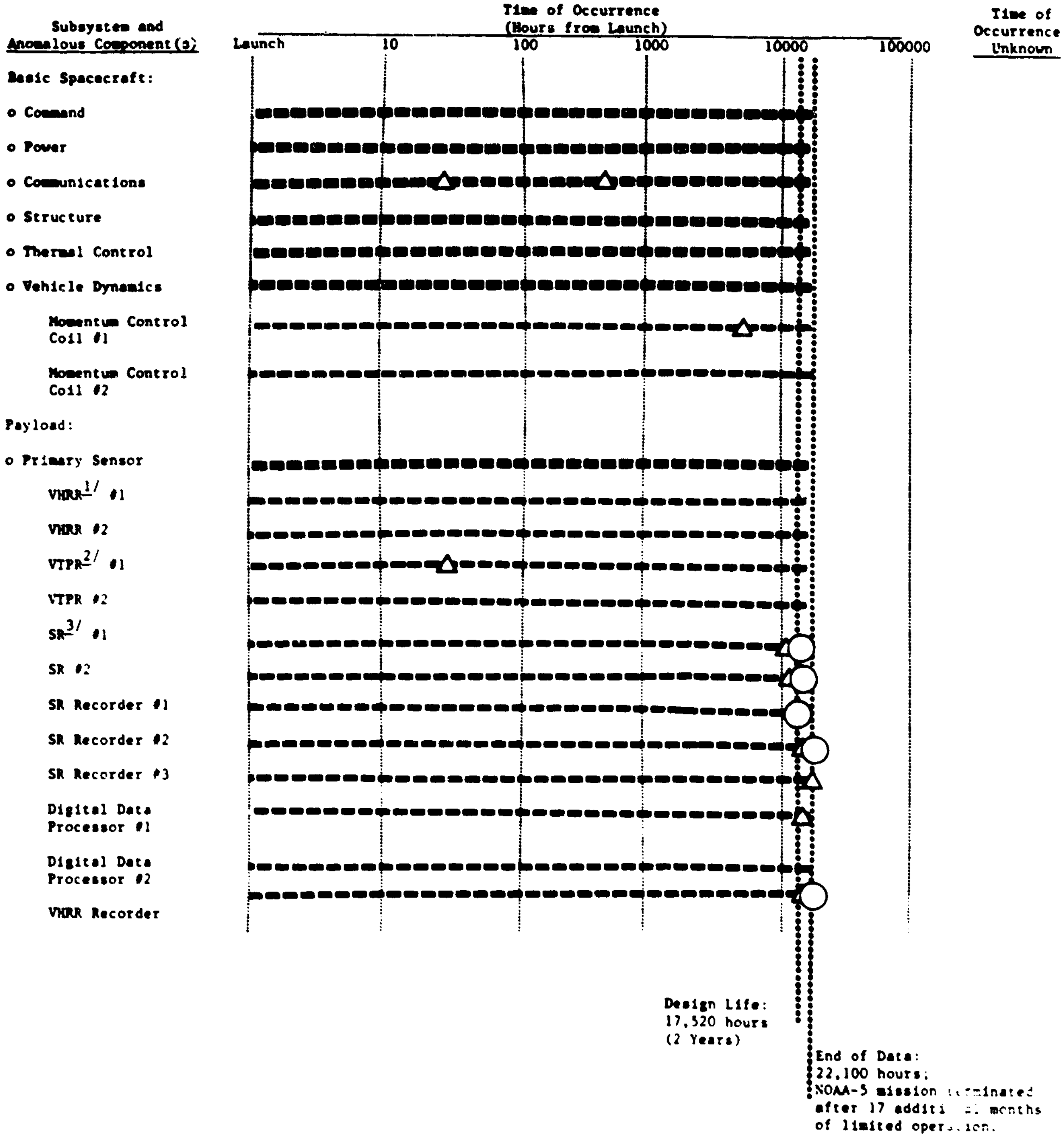
PERFORMANCE SUMMARY FOR NOAA-5



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ VHRR = Very High Resolution Radiometer.
2/ VTPR = Vertical Temperature Profile Radiometer.
3/ SR = Scanning Radiometer.

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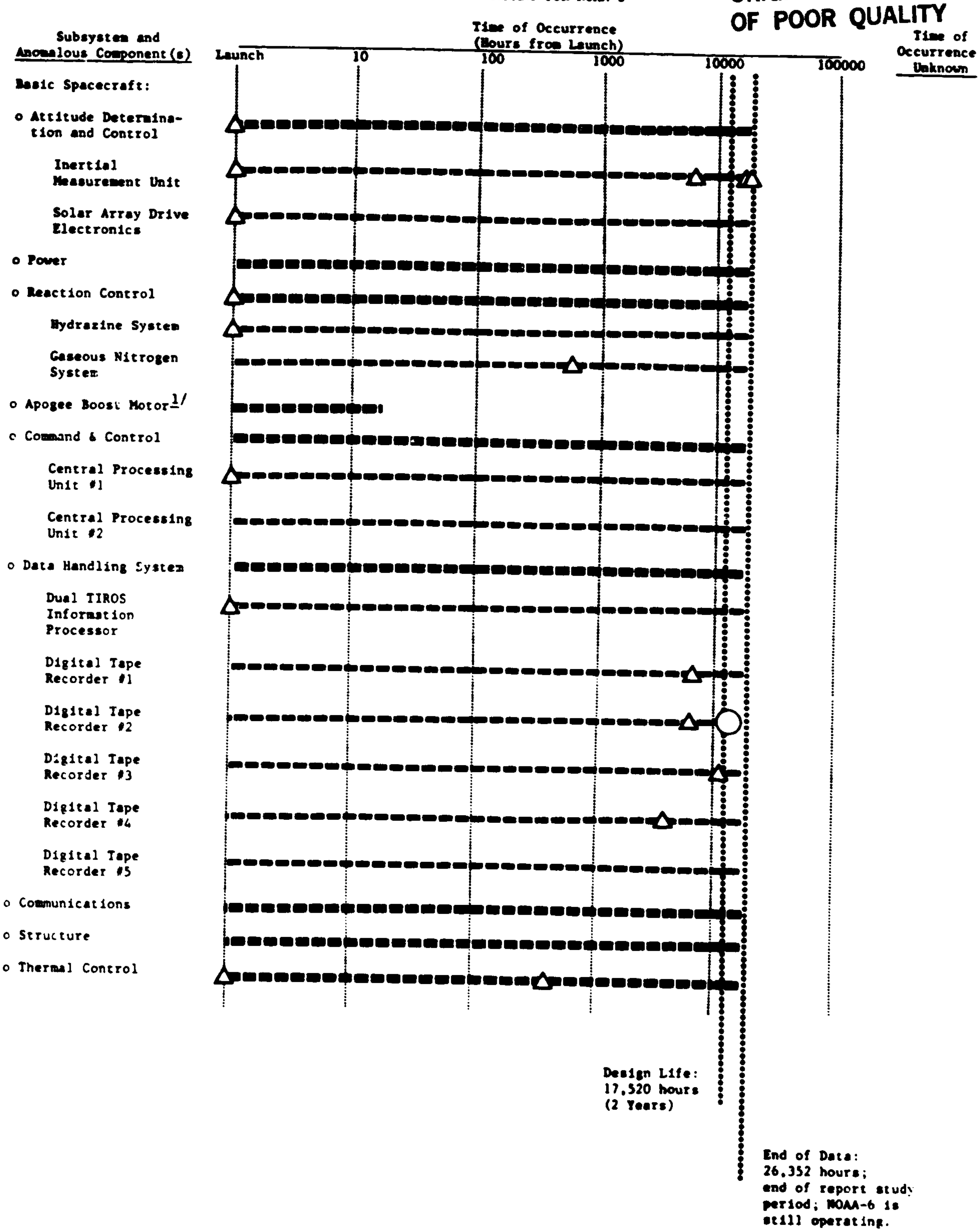
PERFORMANCE SUMMARY FOR NOAA-6



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.

PERFORMANCE SUMMARY FOR NOAA-6
(Continued)

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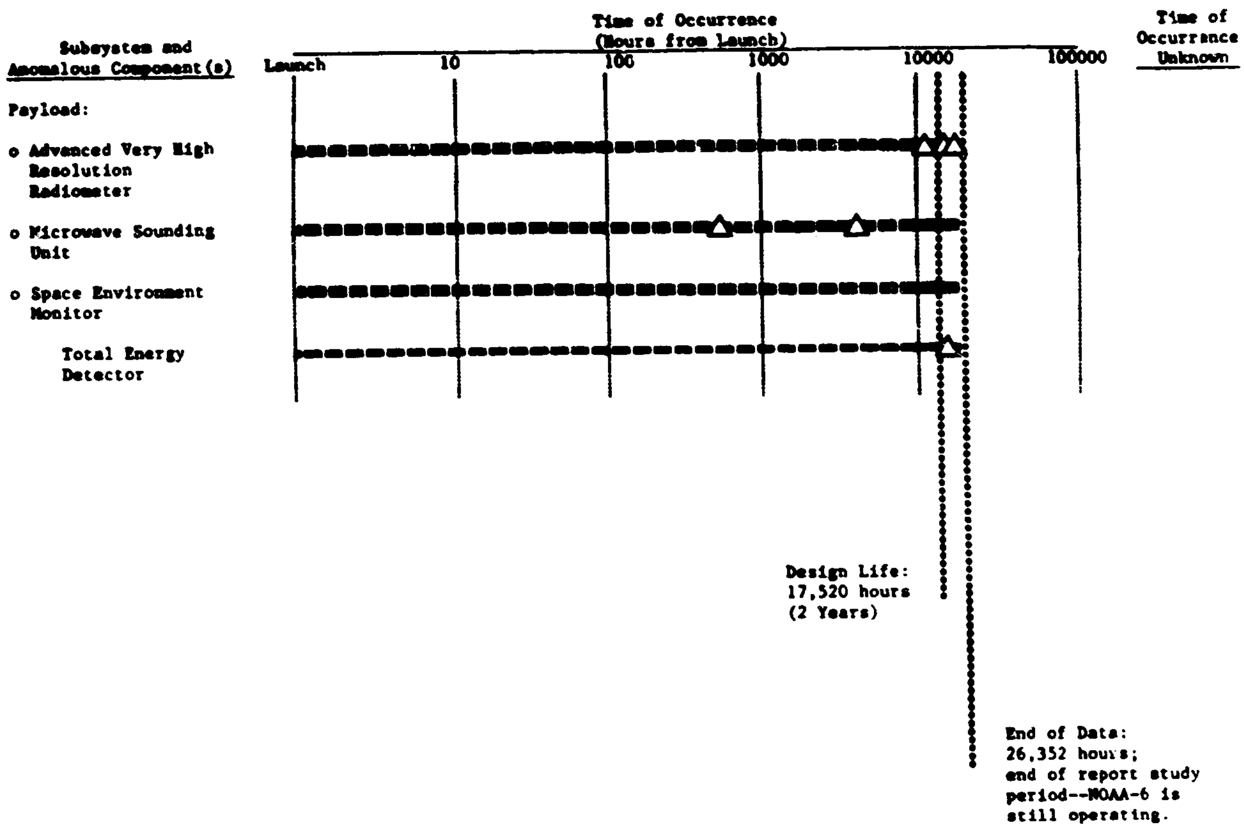

Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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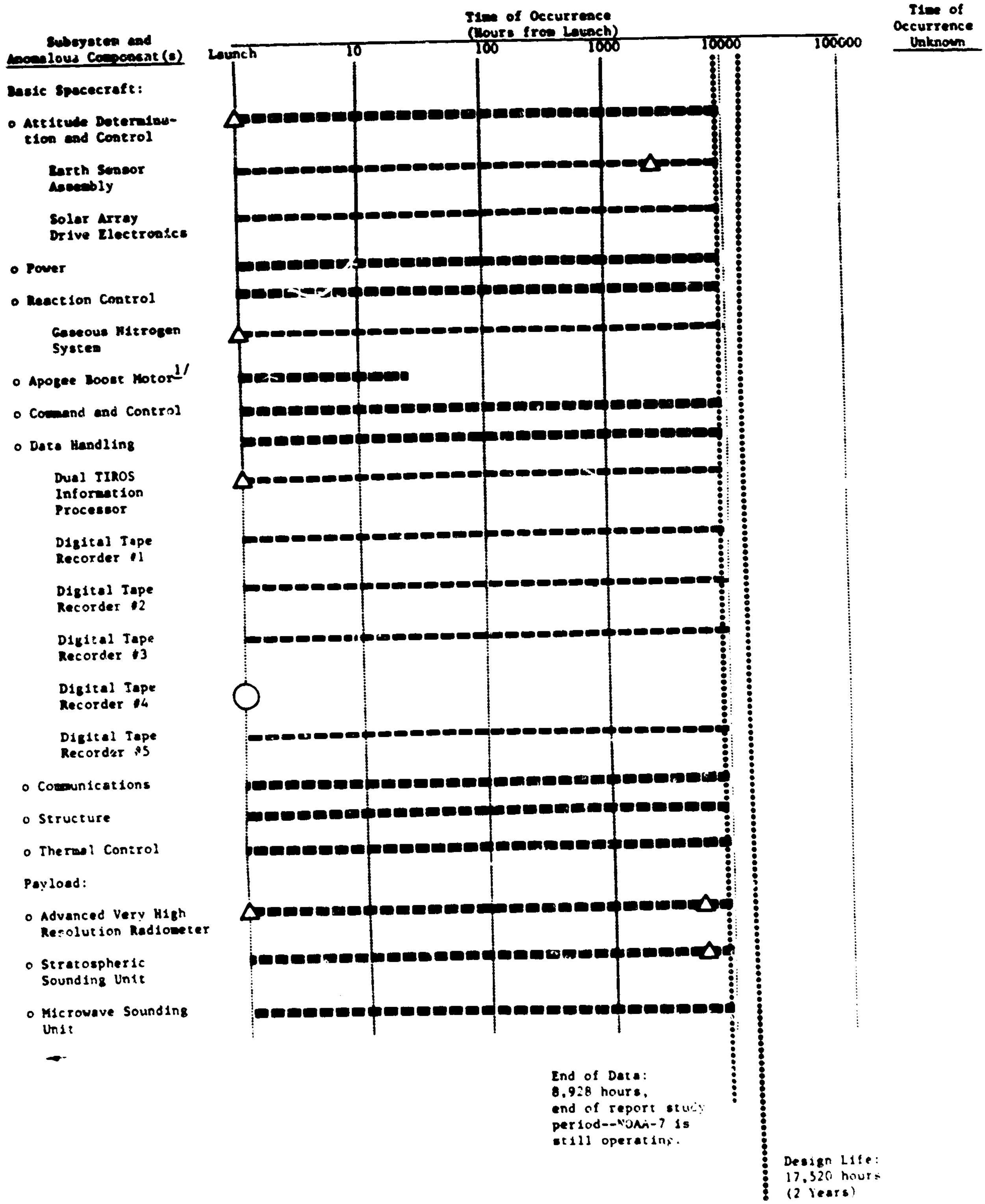
PERFORMANCE SUMMARY FOR NOAA-7



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.

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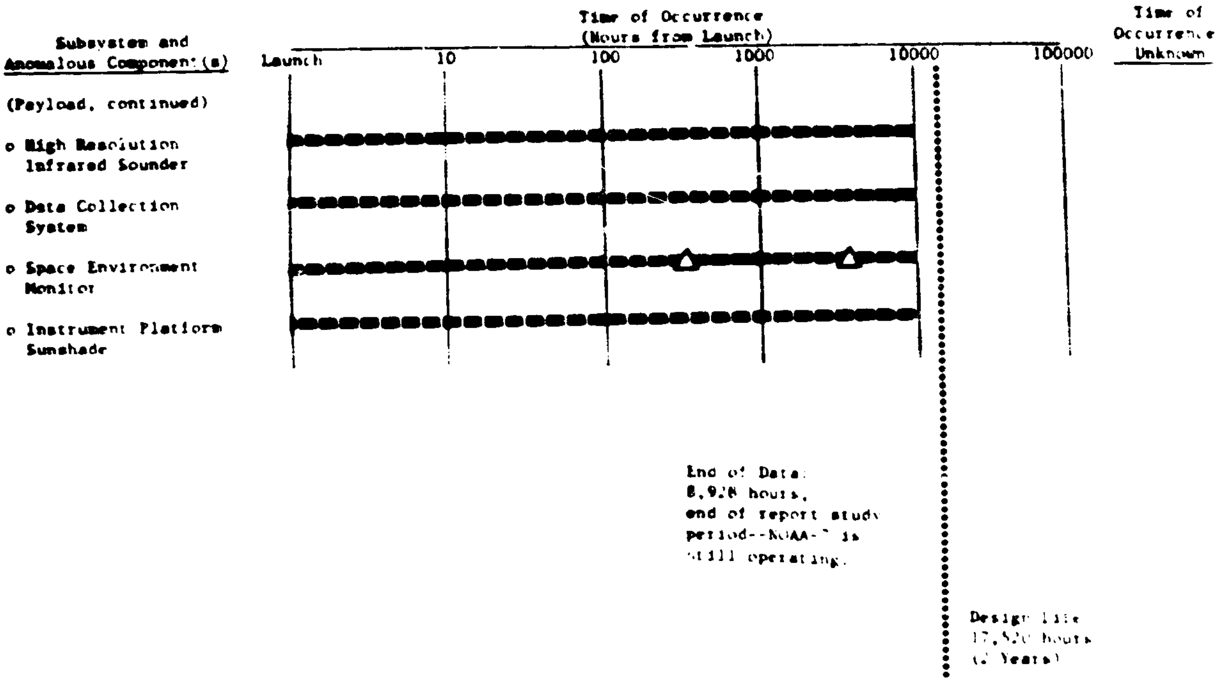
PERFORMANCE SUMMARY FOR NOAA-7
(Continued)



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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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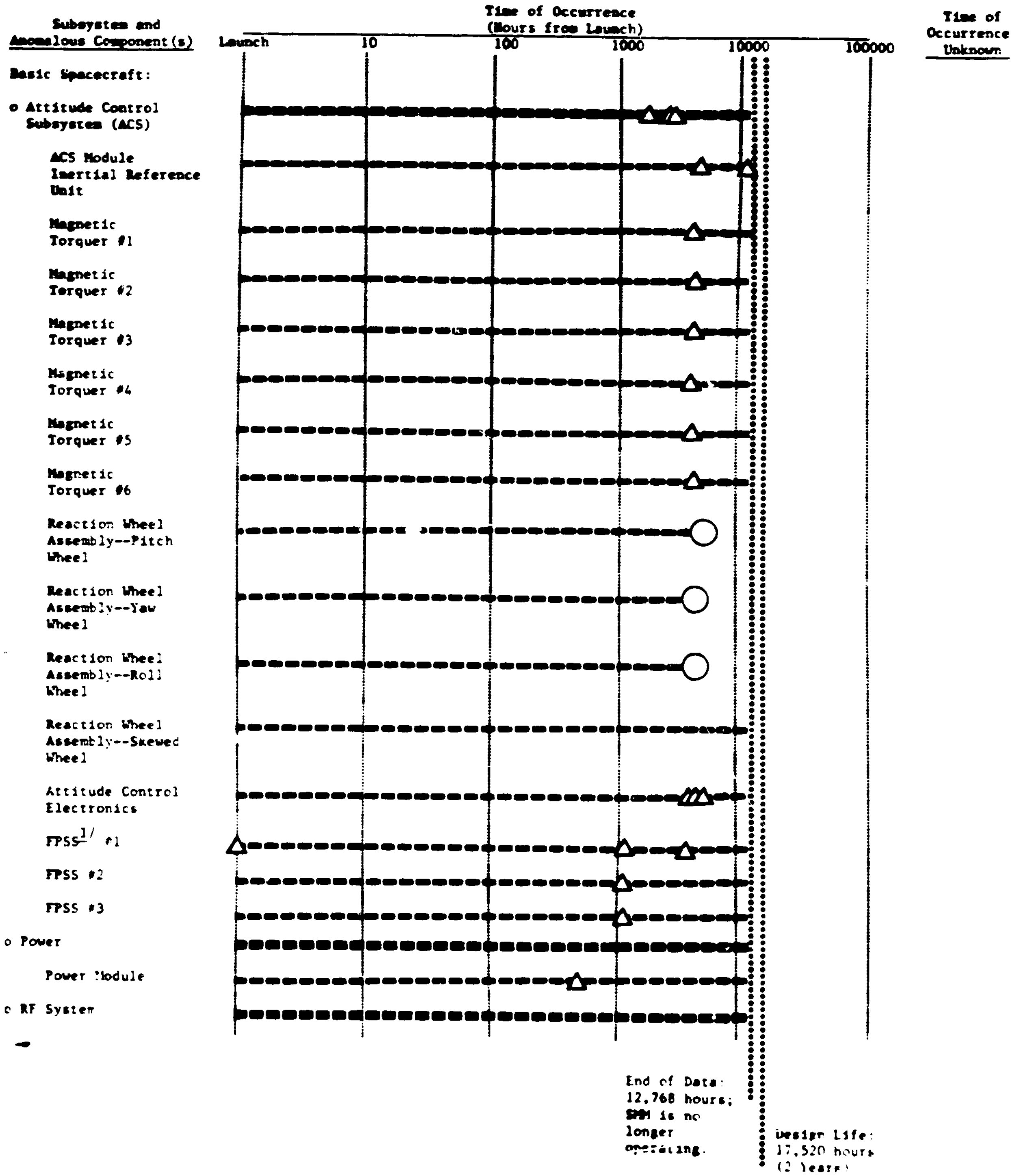
PERFORMANCE SUMMARY FOR SMM



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ FPSS = Fine Pointing Sun Sensors

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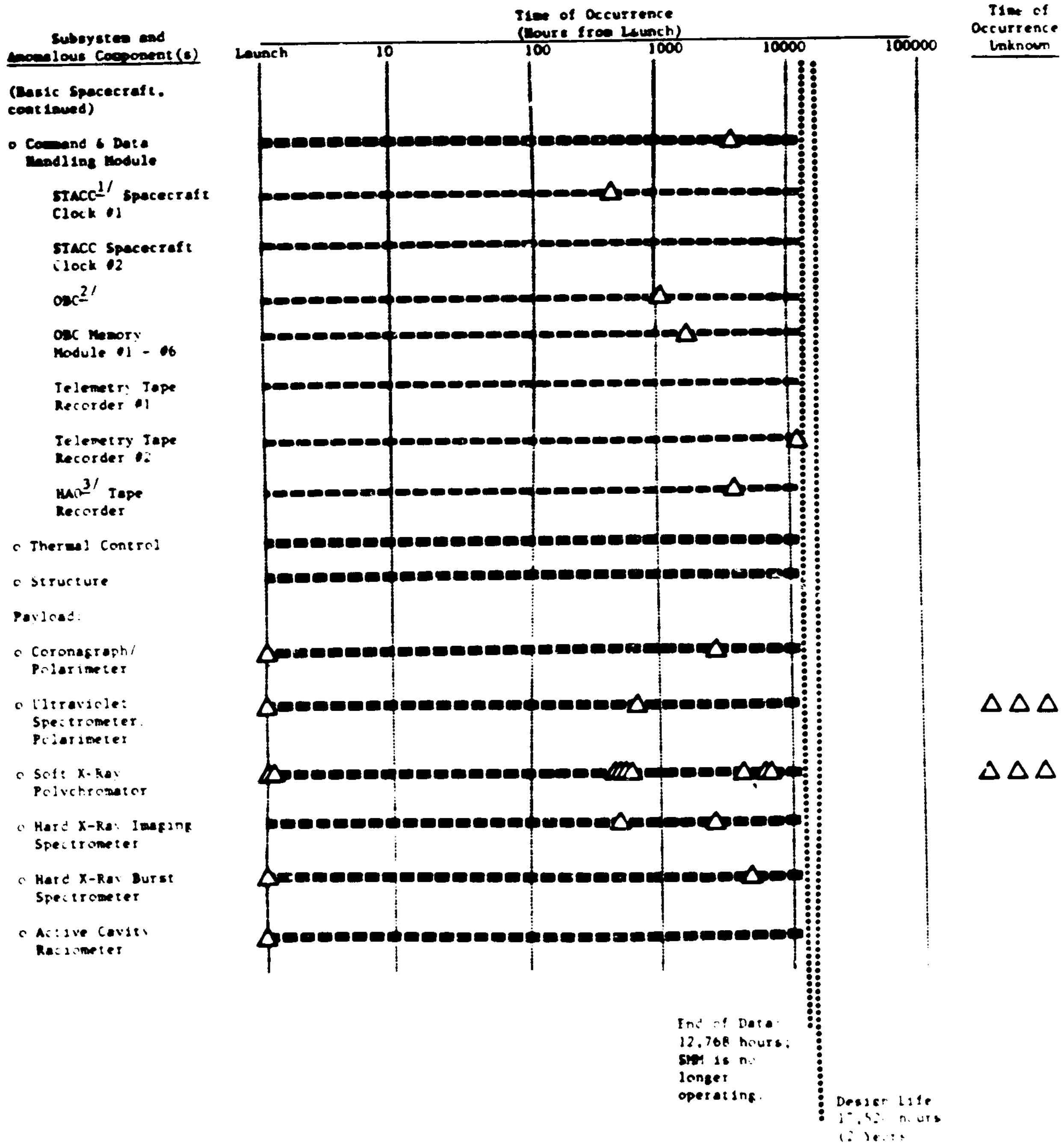
PERFORMANCE SUMMARY FOR SMM
(Continued)



Legend:

indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1. STACC = Standard Telemetry and Command Components.
2. OBC = On-Board Computer
3. HAO = High Altitude Observatory

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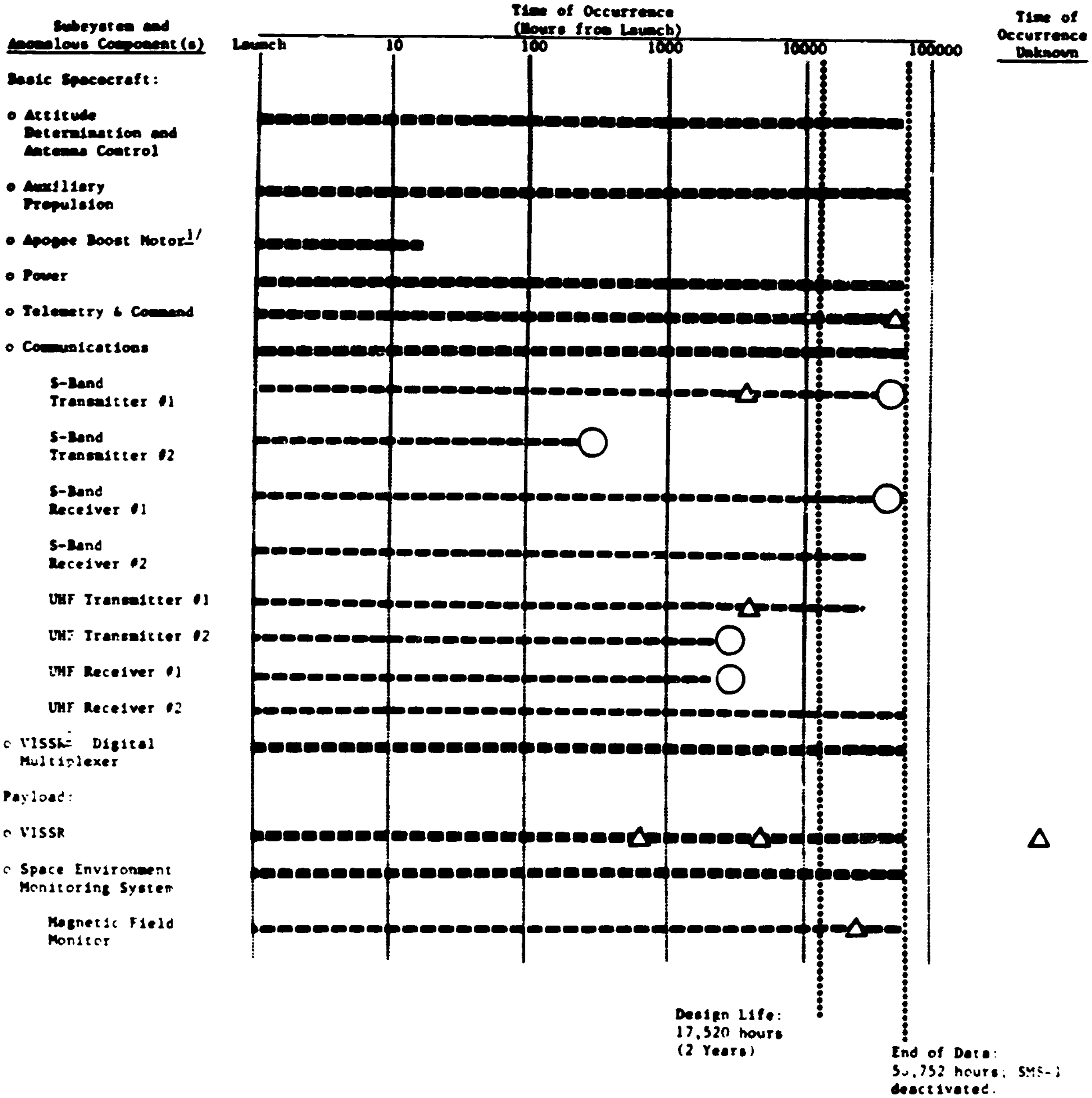
PERFORMANCE SUMMARY FOR SMS-1



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.
2/ VISSR = Visable Infrared Spin Scan Radiometer.

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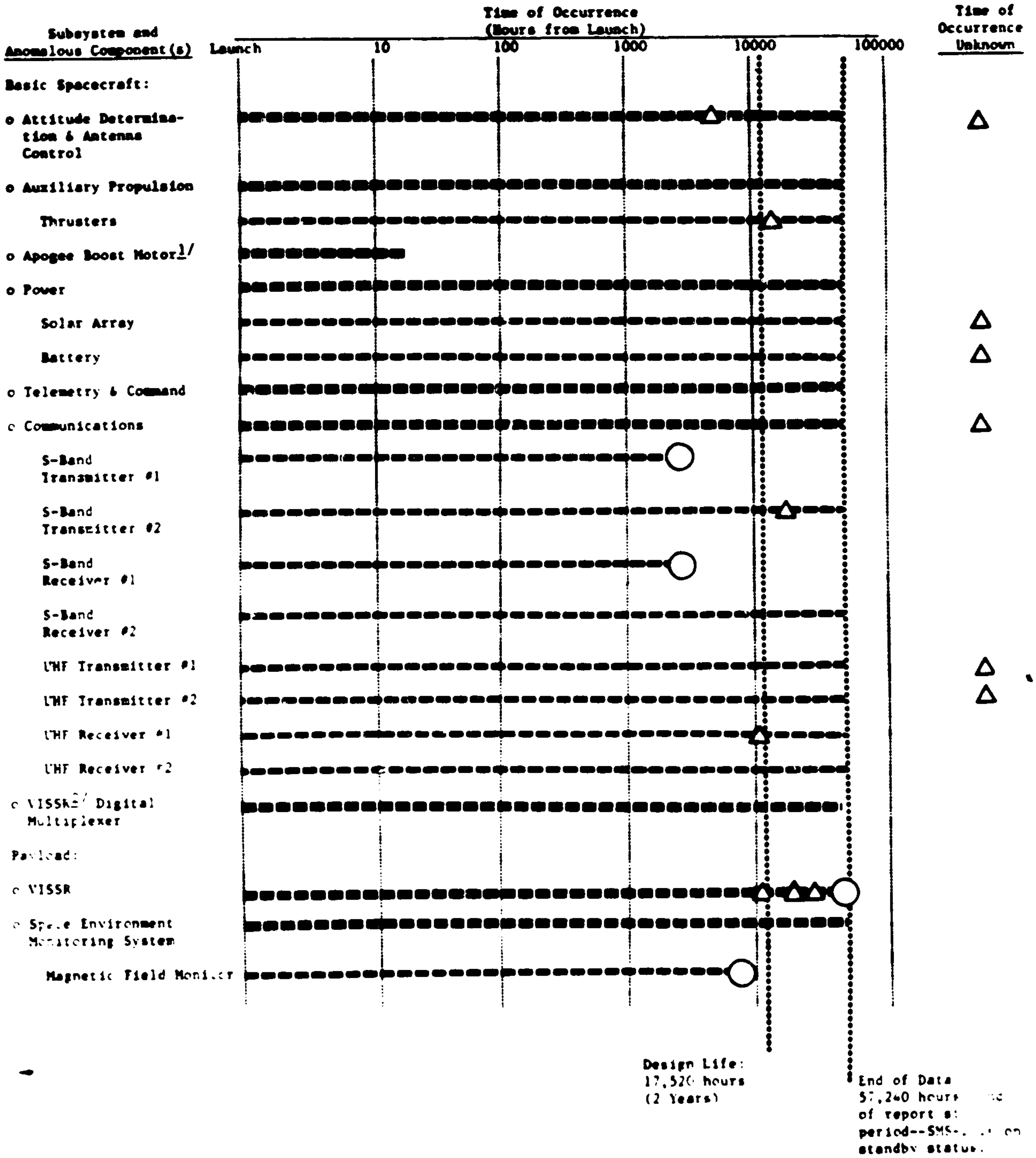
PERFORMANCE SUMMARY FOR SMS-2



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.
2/ VISSR = Visable Infrared Spin Scan Radiometer.

PERFORMANCE SUMMARY FOR TIROS-N

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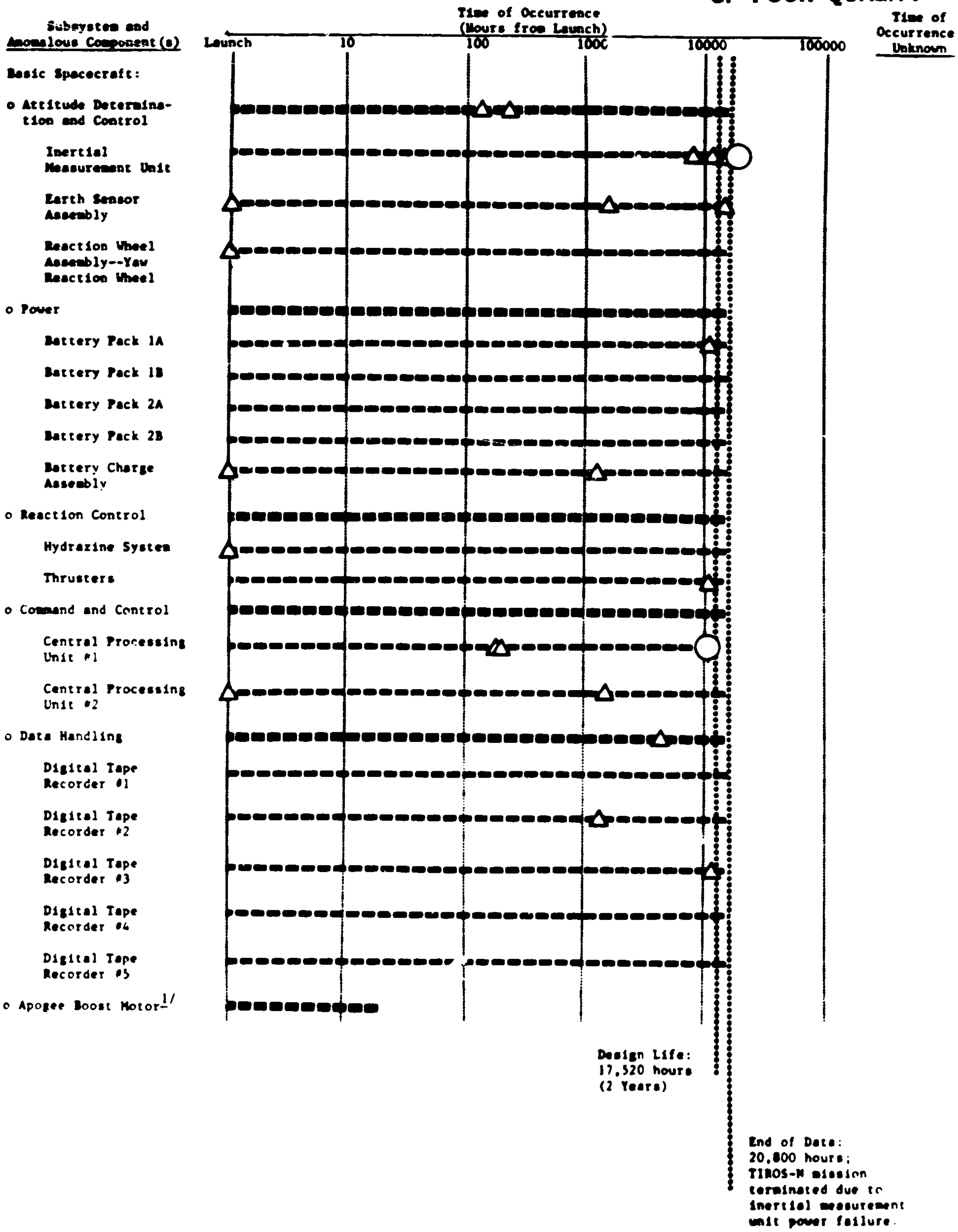

Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ The apogee boost motor is a one-shot device and has a normal lifetime of 24 hours.

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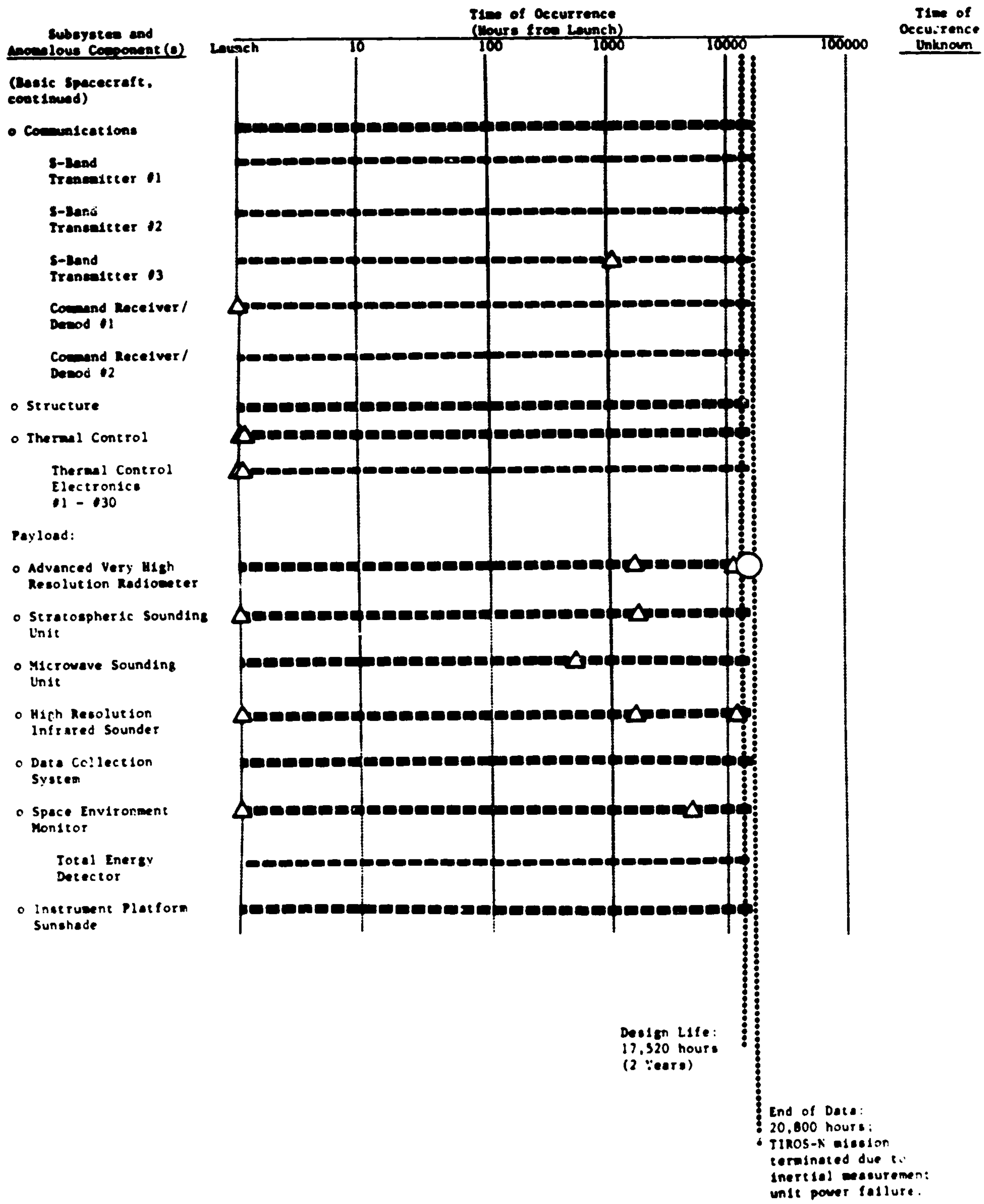
PERFORMANCE SUMMARY FOR TIROS-N
(Continued)



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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

PERFORMANCE SUMMARY FOR SEASAT

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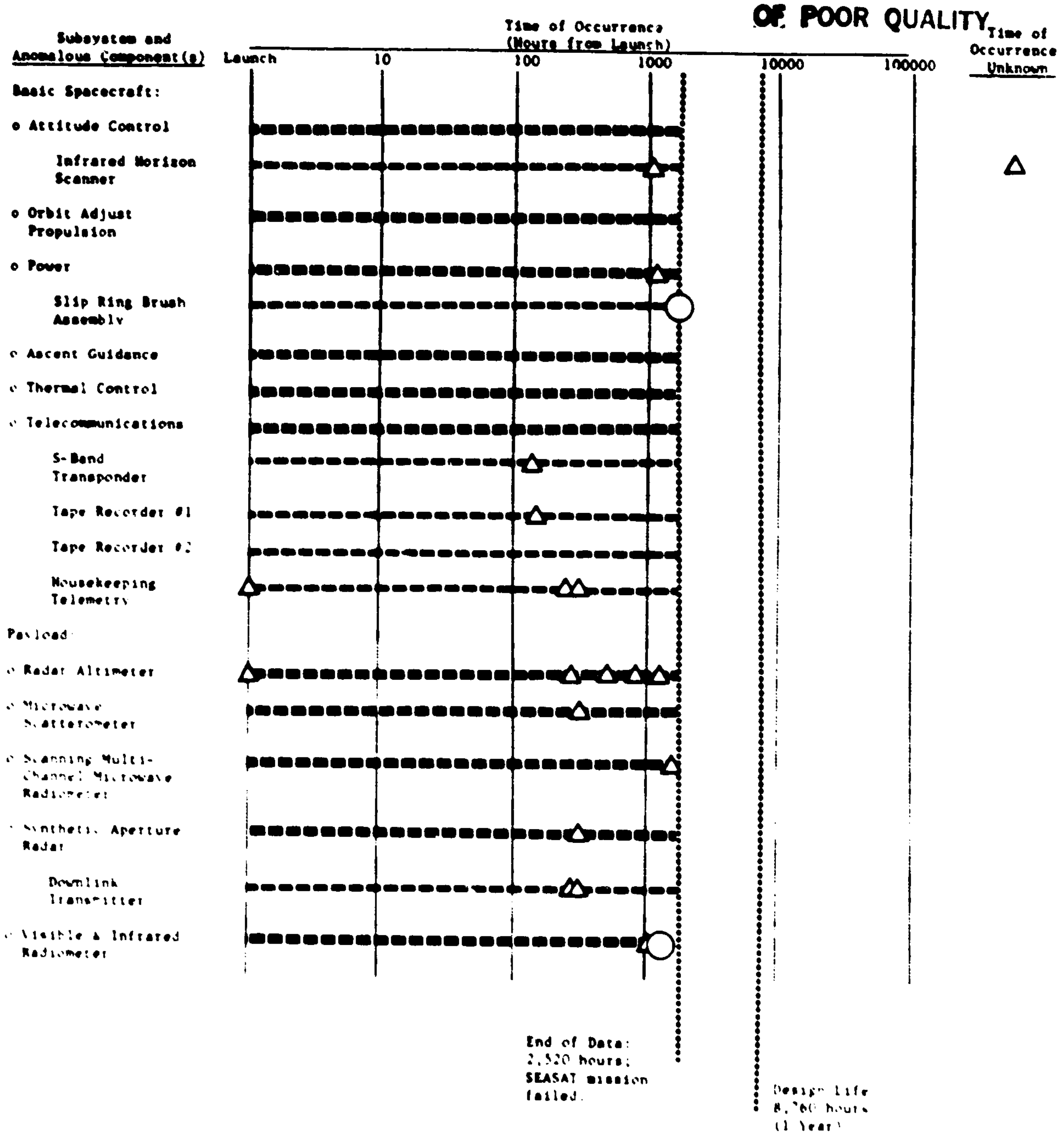

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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable

△ indicates that this anomaly is not a failure

PERFORMANCE SUMMARY FOR SMM

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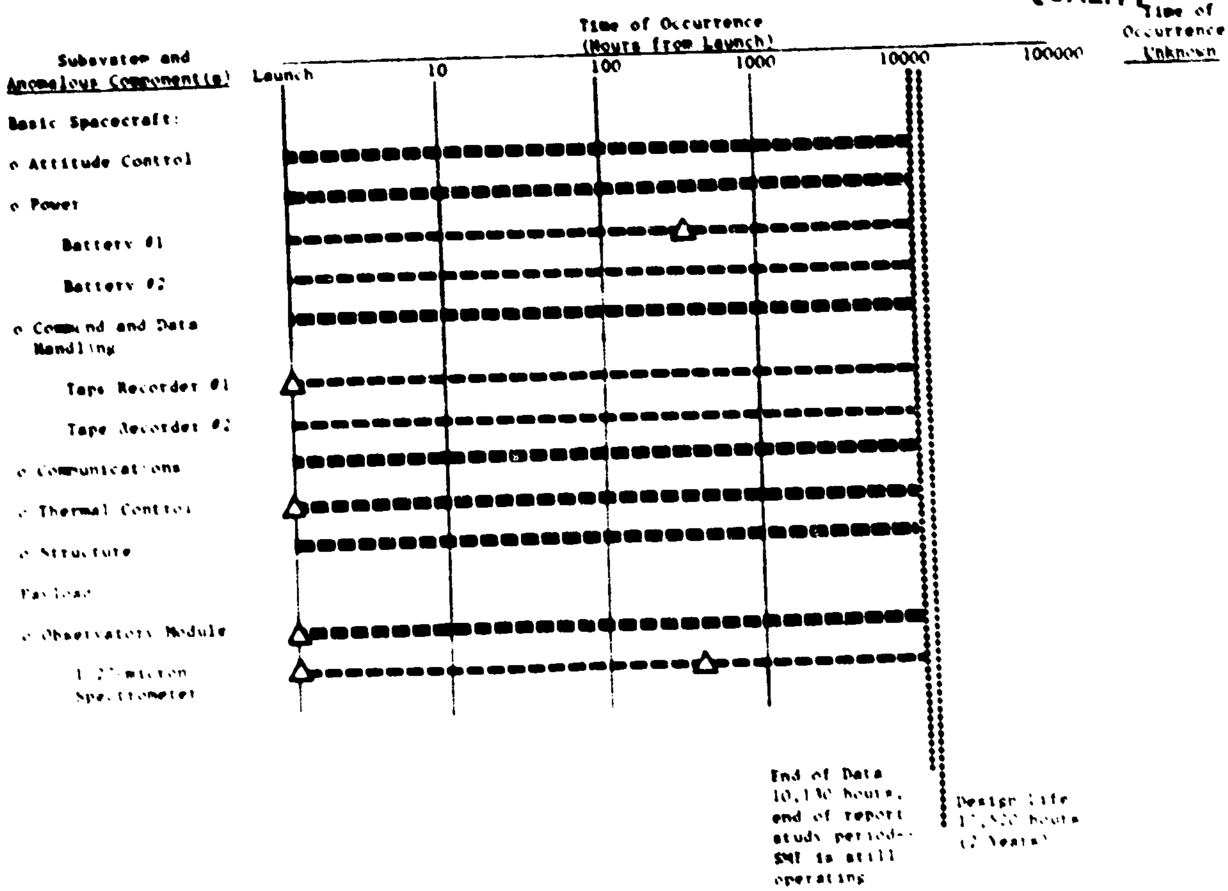

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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable

△ indicates that this anomaly is not a failure

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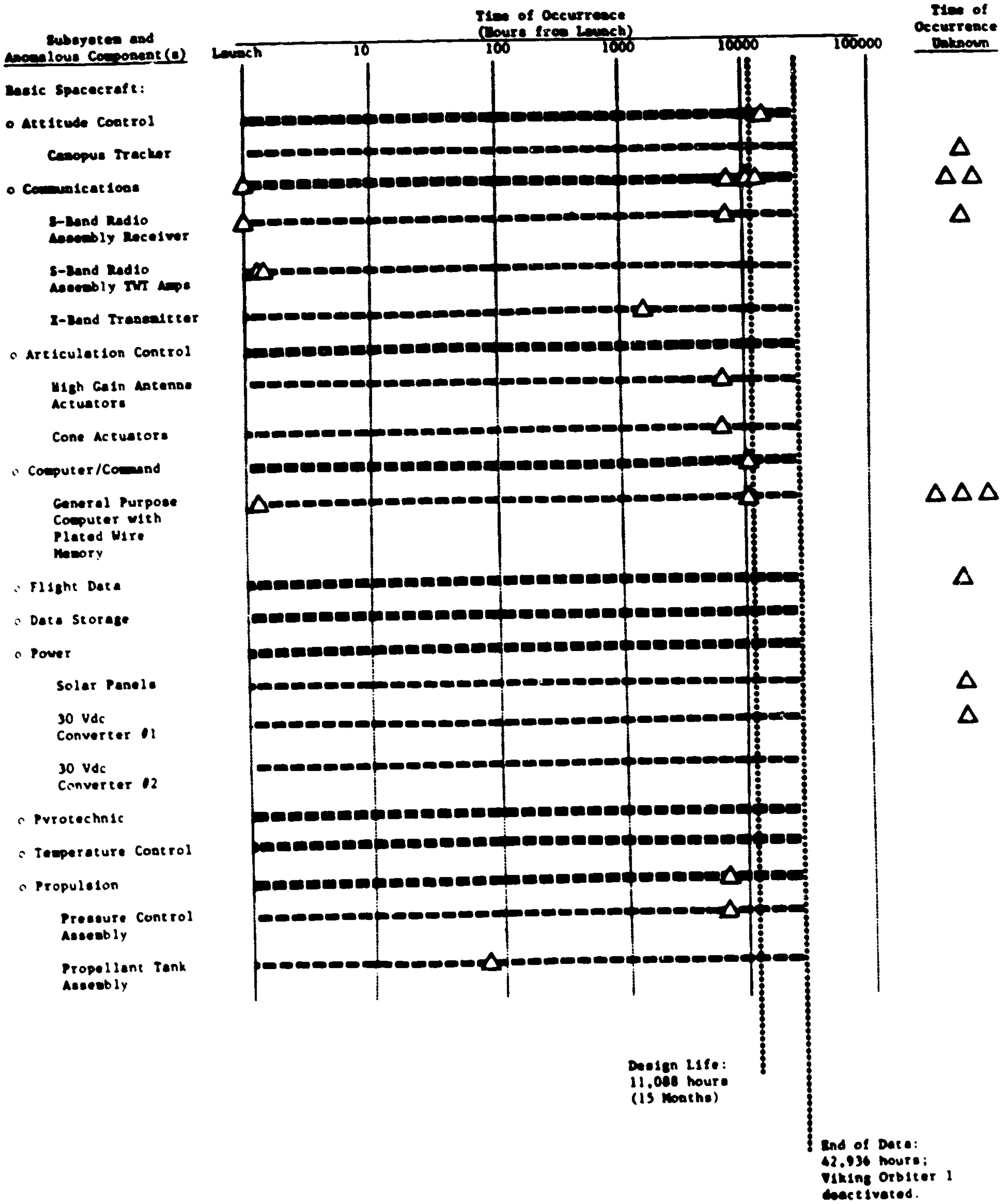
PERFORMANCE SUMMARY FOR VIKING ORBITER 1



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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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PERFORMANCE SUMMARY FOR VIKING ORBITER 1
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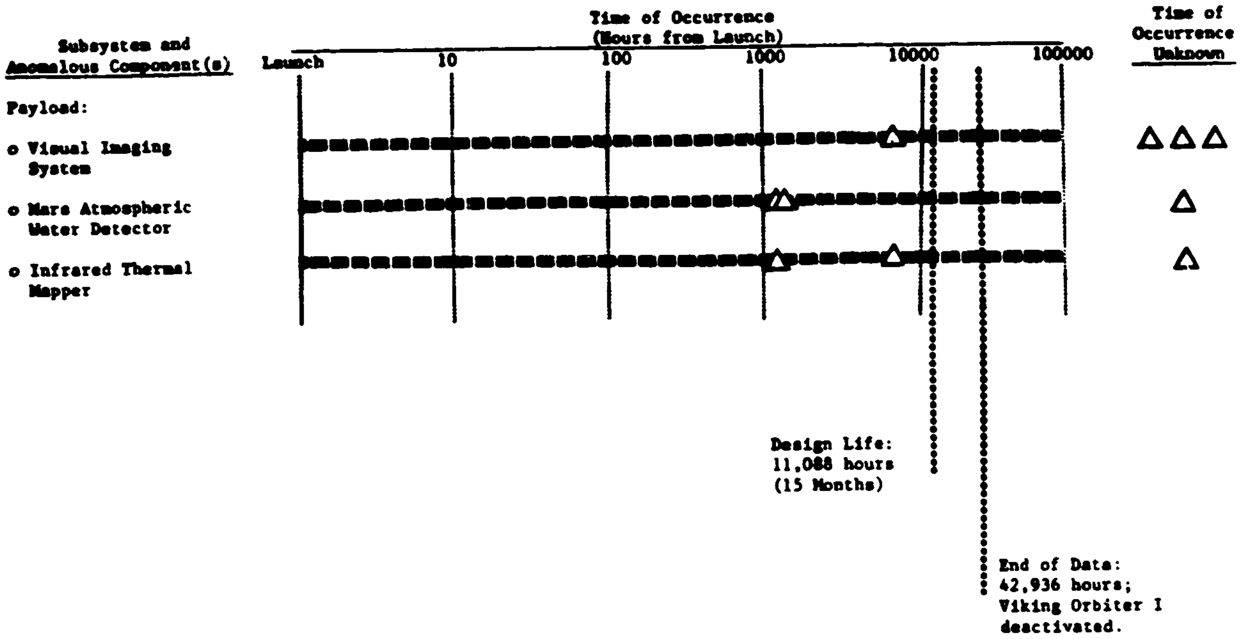

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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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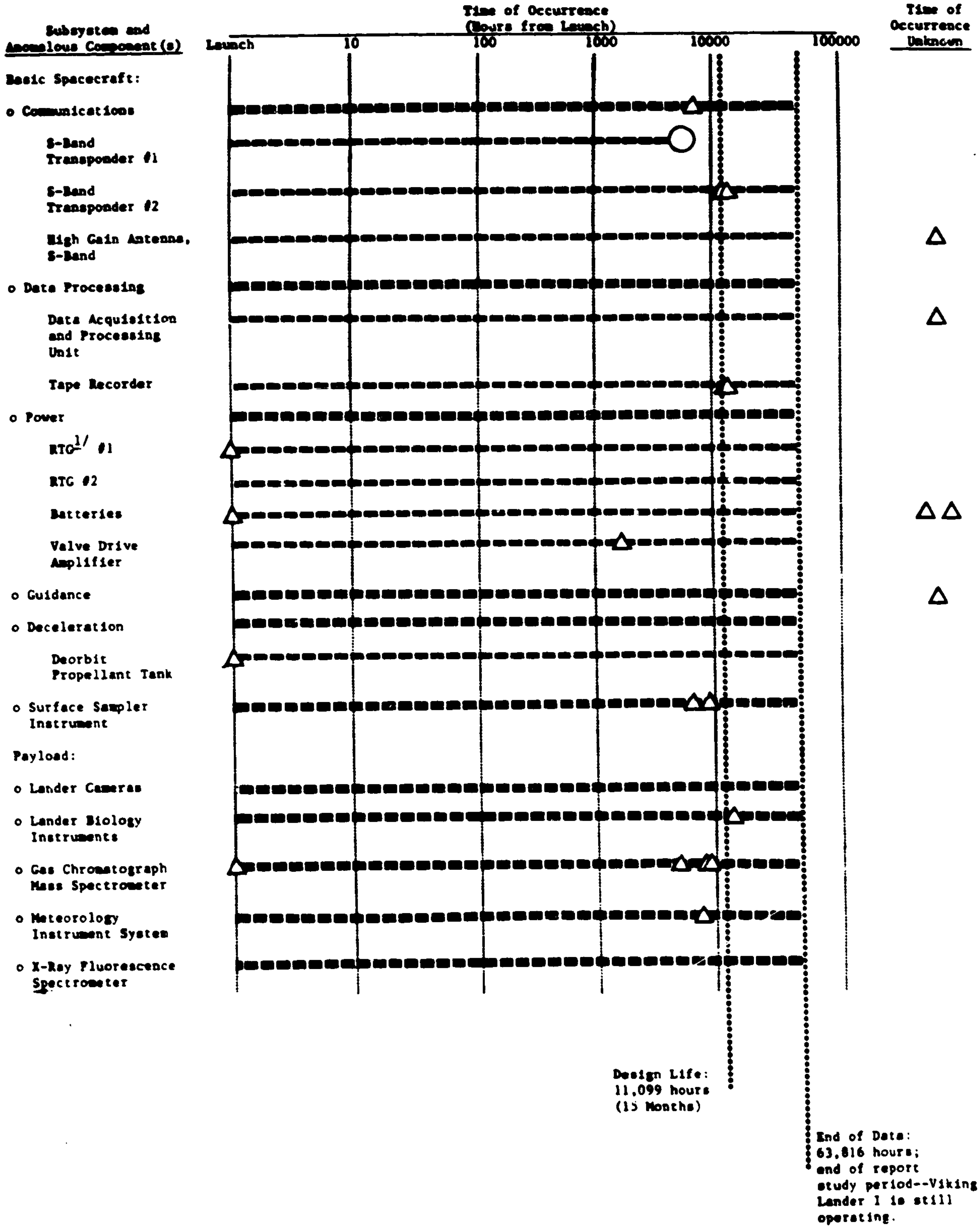
PERFORMANCE SUMMARY FOR VIKING LANDER 1



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ RTG = Radioisotope Thermoelectric Generator.

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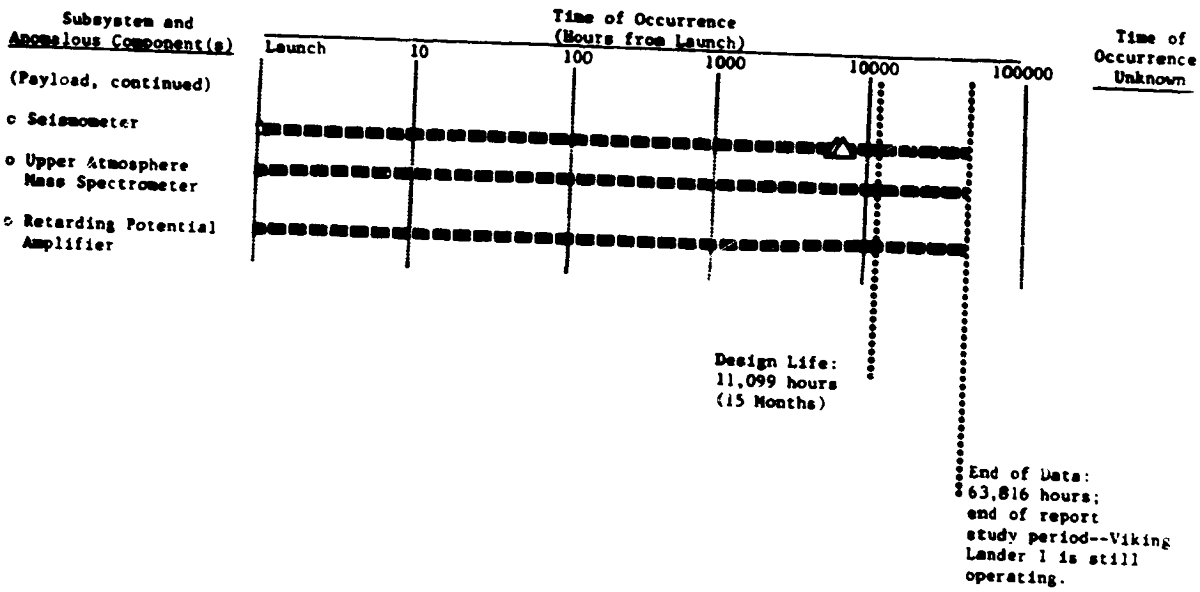
PERFORMANCE SUMMARY FOR VIKING LANDER 1
(Continued)



Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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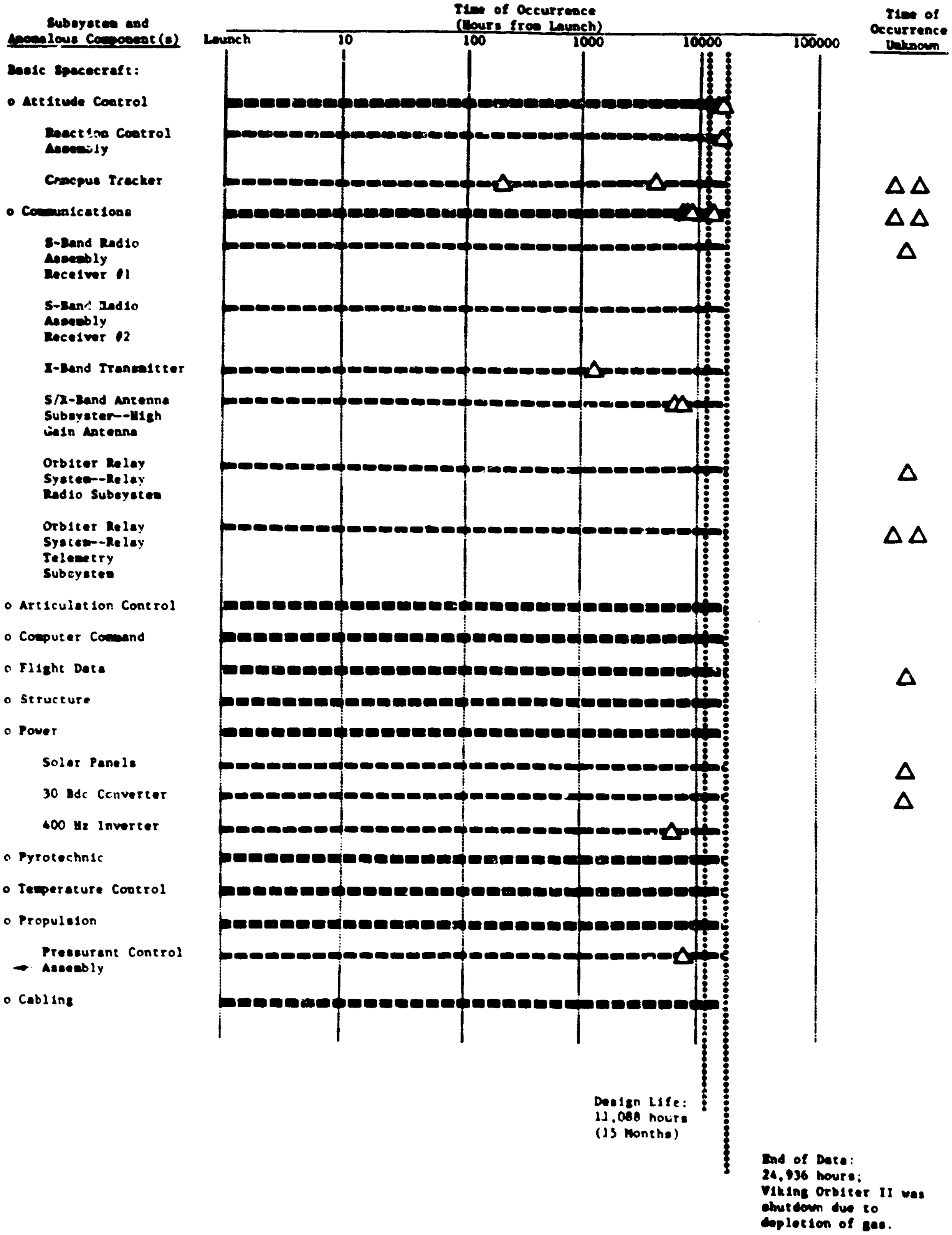
PERFORMANCE SUMMARY FOR VIKING ORBITER 2



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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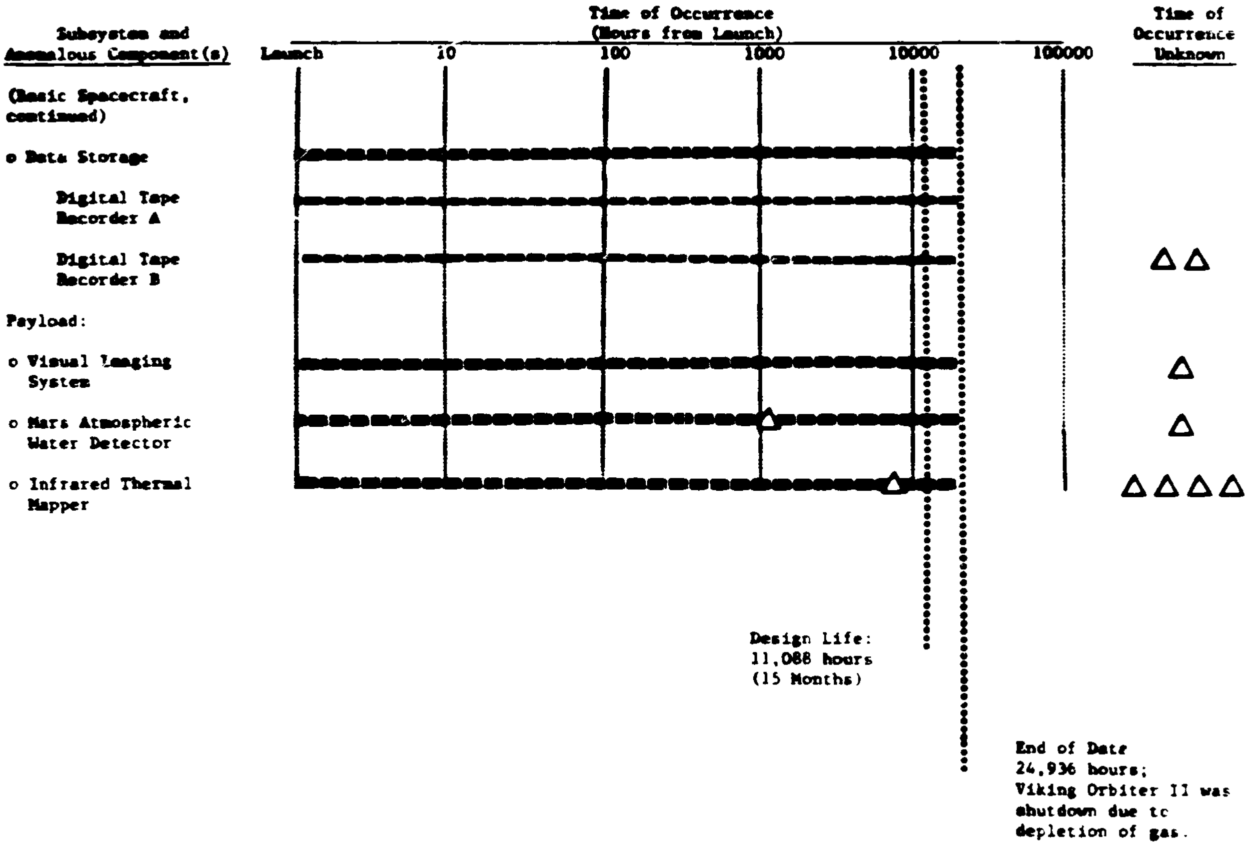

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◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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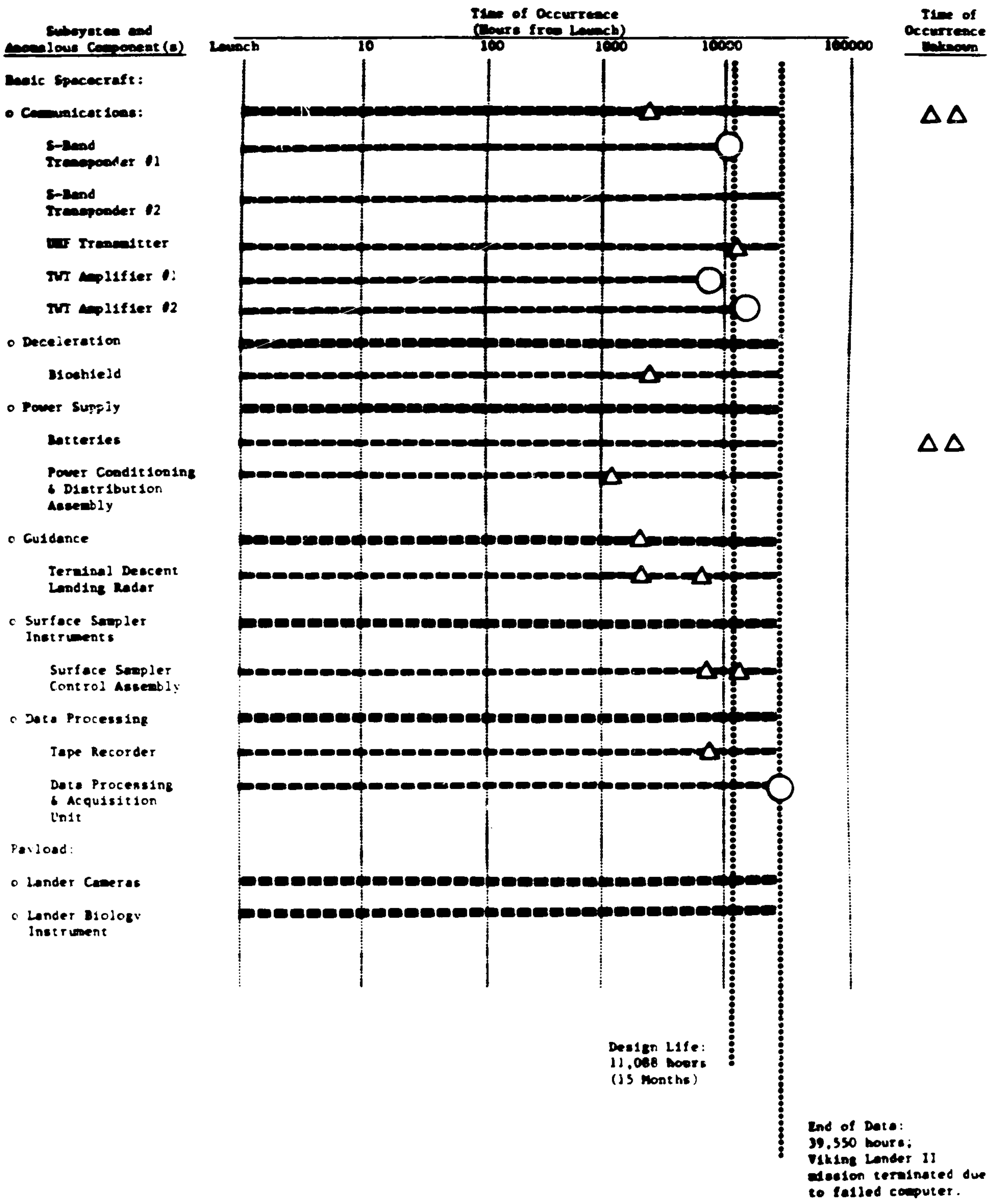
PERFORMANCE SUMMARY FOR VIKING LANDER 2



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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PERFORMANCE SUMMARY FOR VIKING LANDER 2
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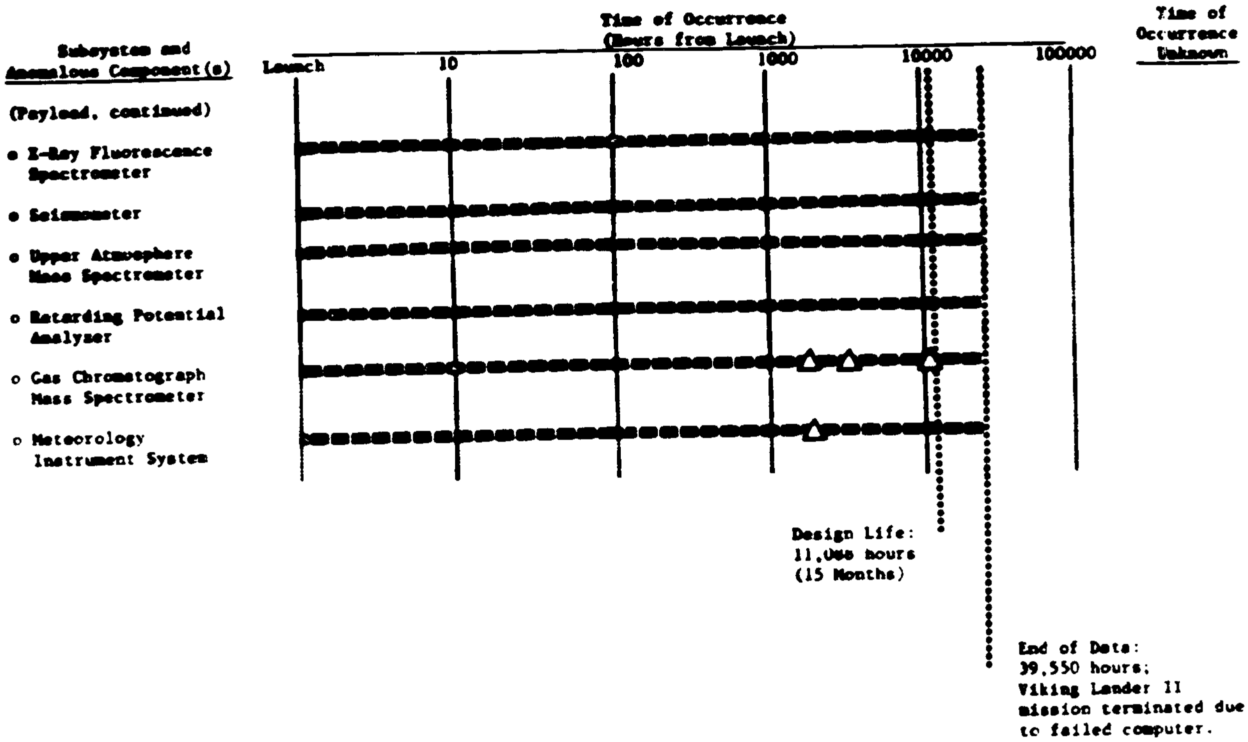

Legend:

◯ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is <u>not</u> a failure.

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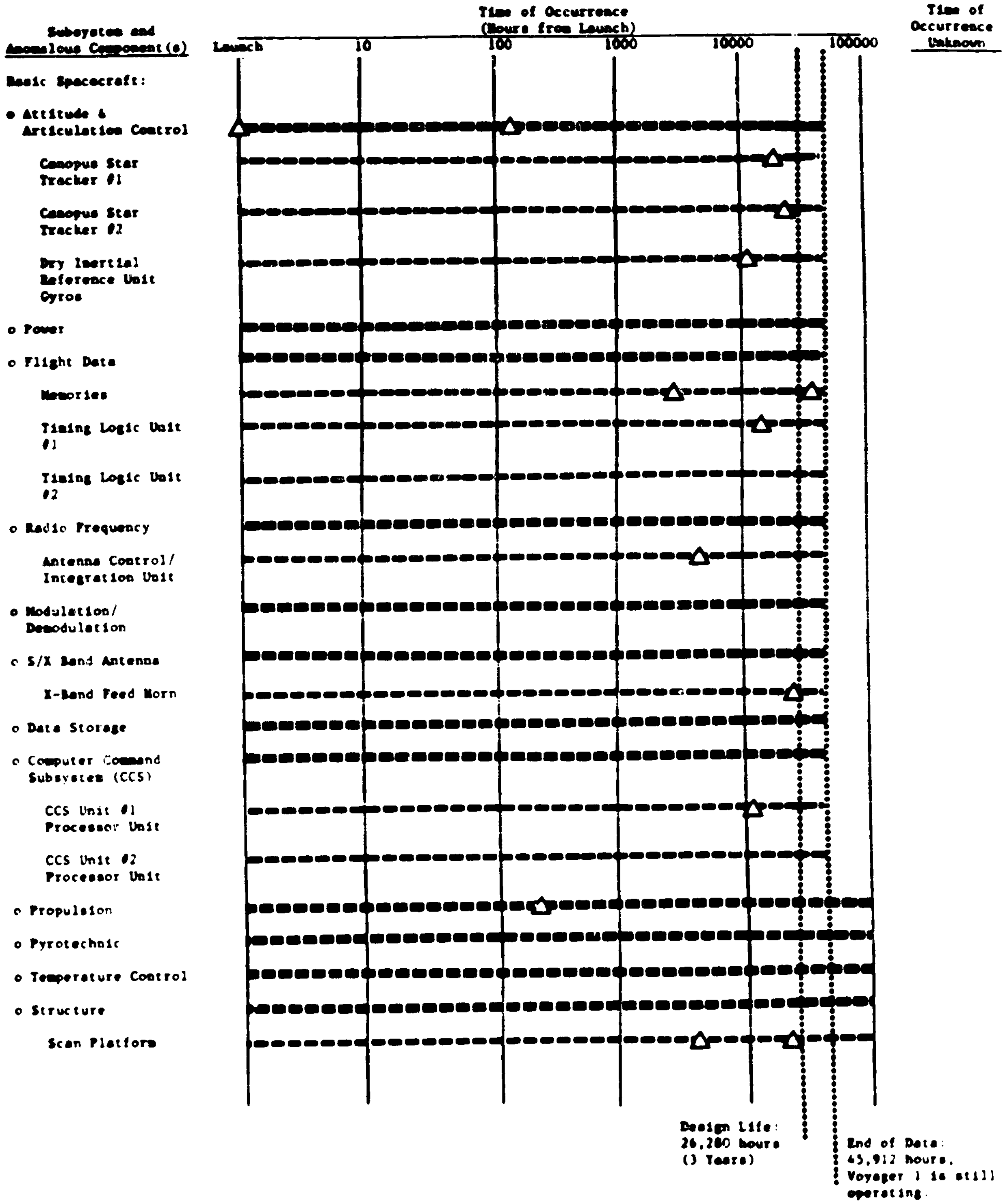
PERFORMANCE SUMMARY FOR VOYAGER 1



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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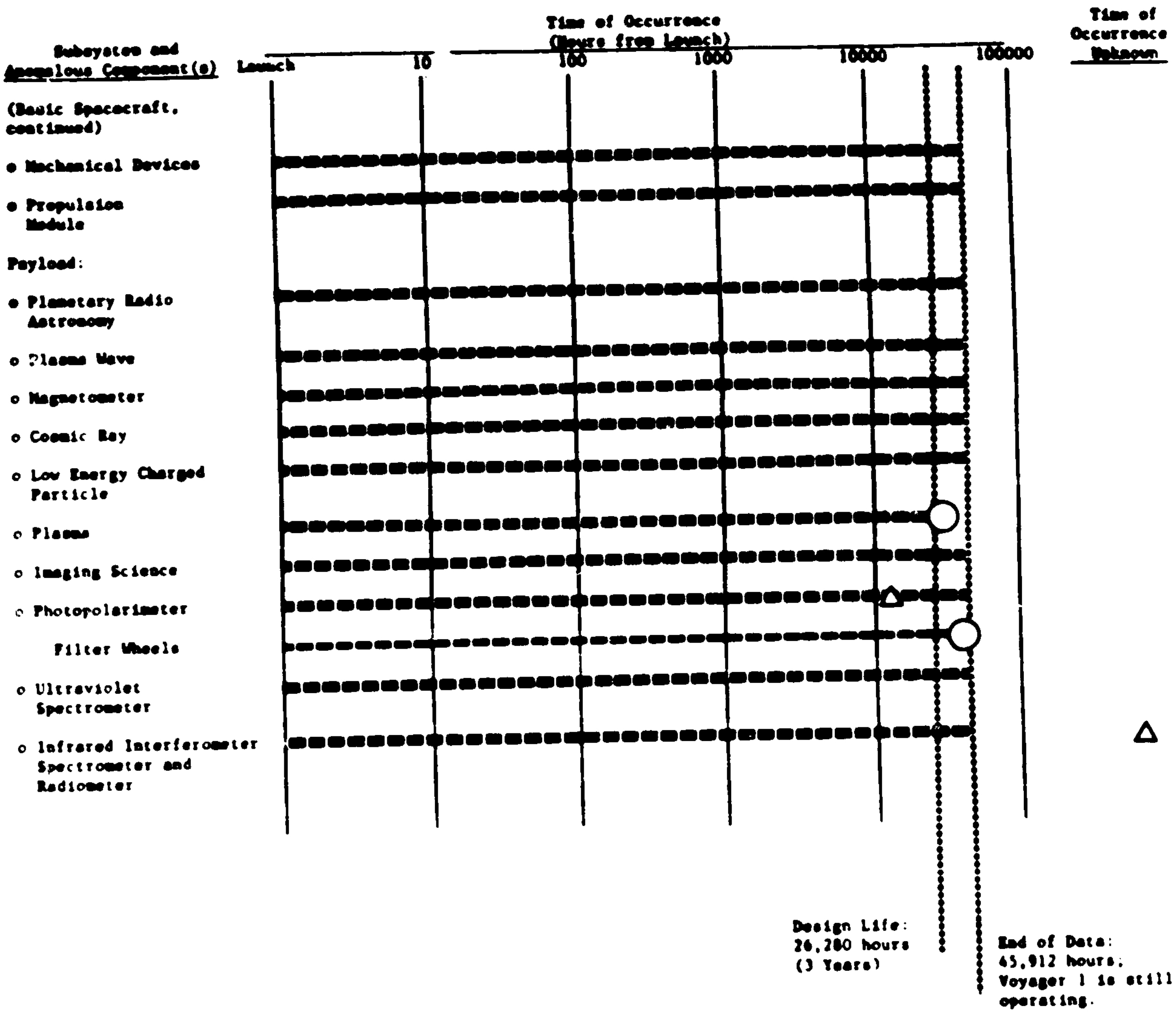
PERFORMANCE SUMMARY FOR VOYAGER 1
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

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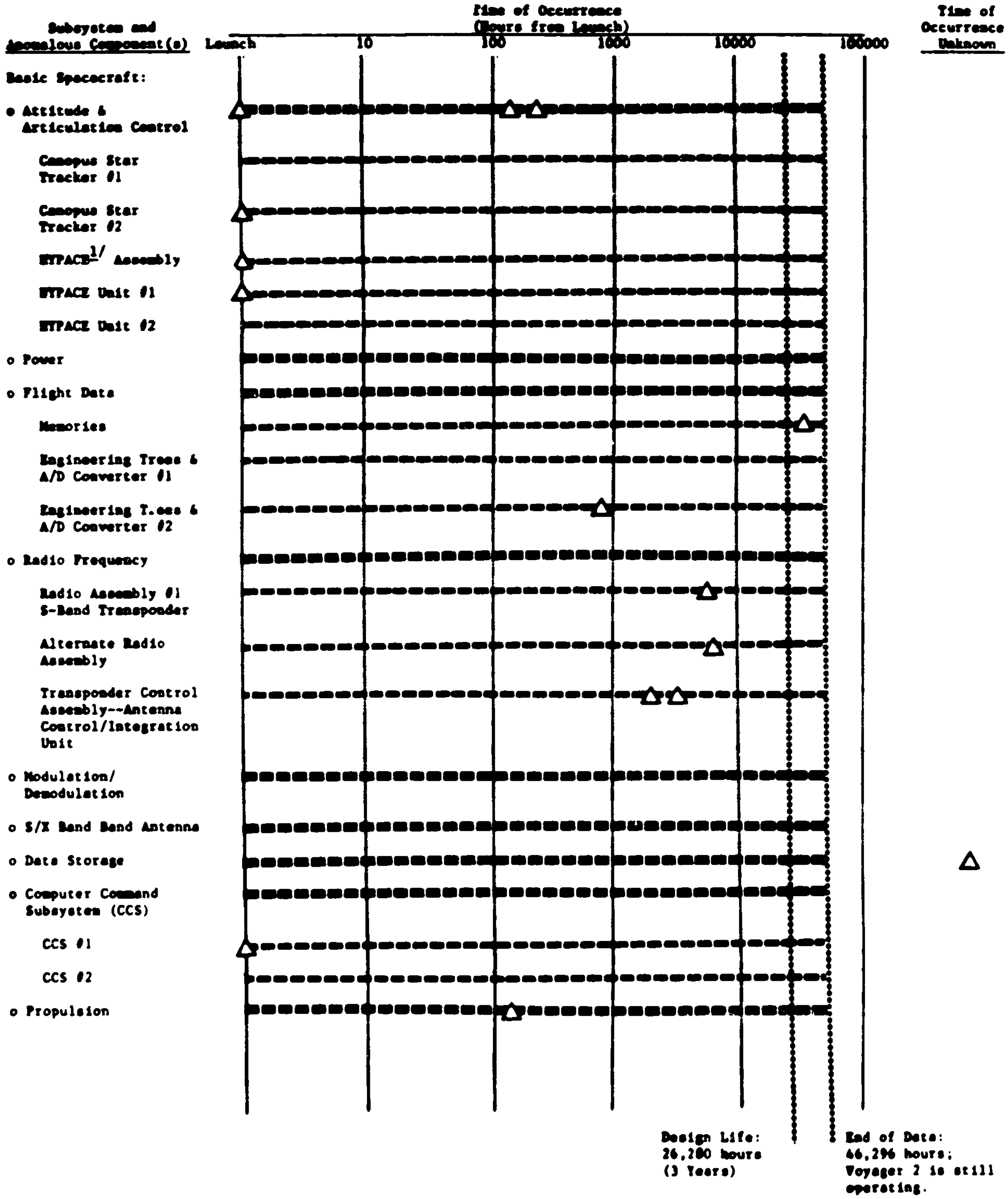
PERFORMANCE SUMMARY FOR VOYAGER 2



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

1/ HYPACE = Hybrid Programmable Attitude Control Electronics.

PERFORMANCE SUMMARY FOR VOYAGER 2
(Continued)

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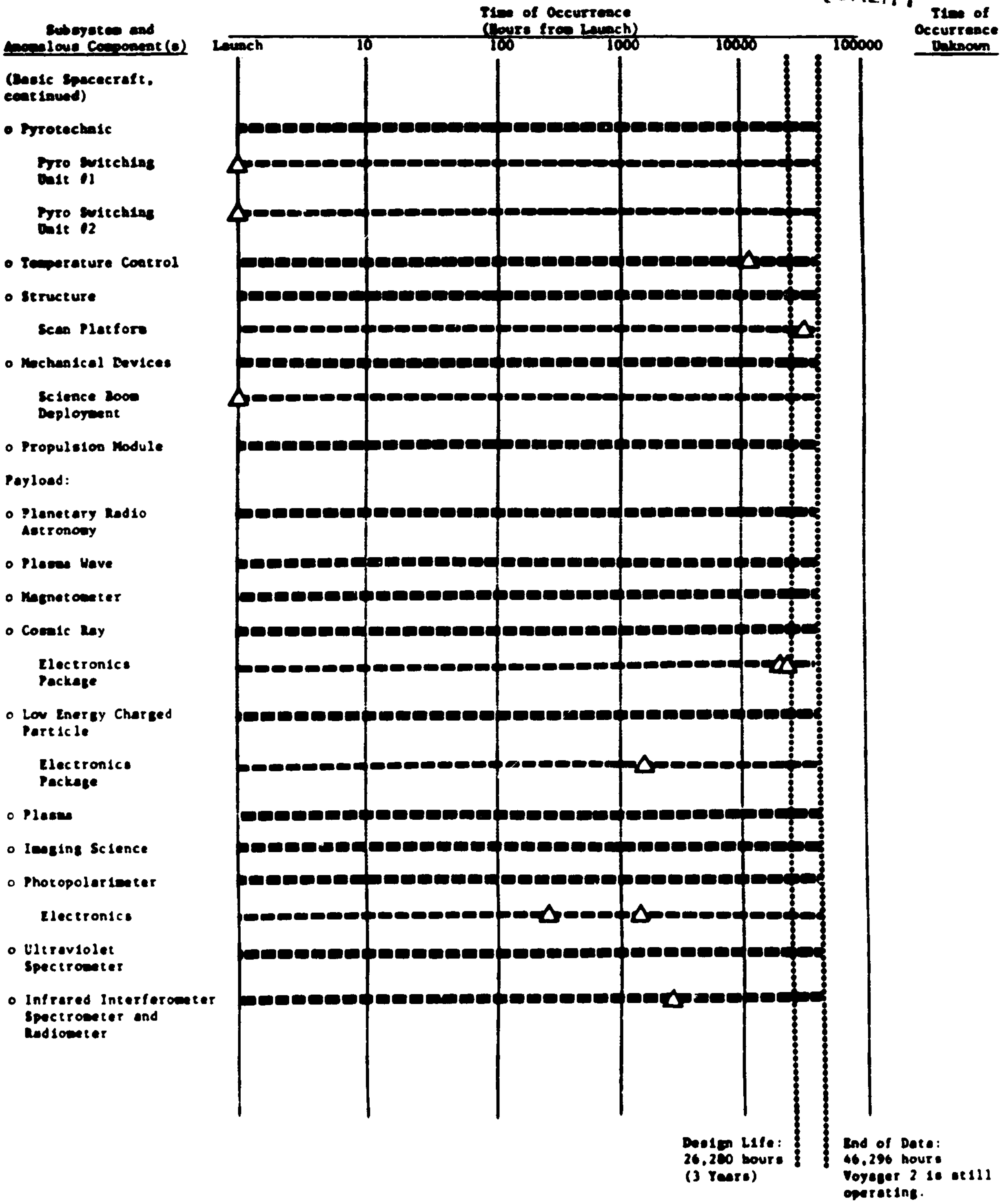

Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates that this anomaly is not a failure.

APPENDIX C-2

SUBSYSTEMS

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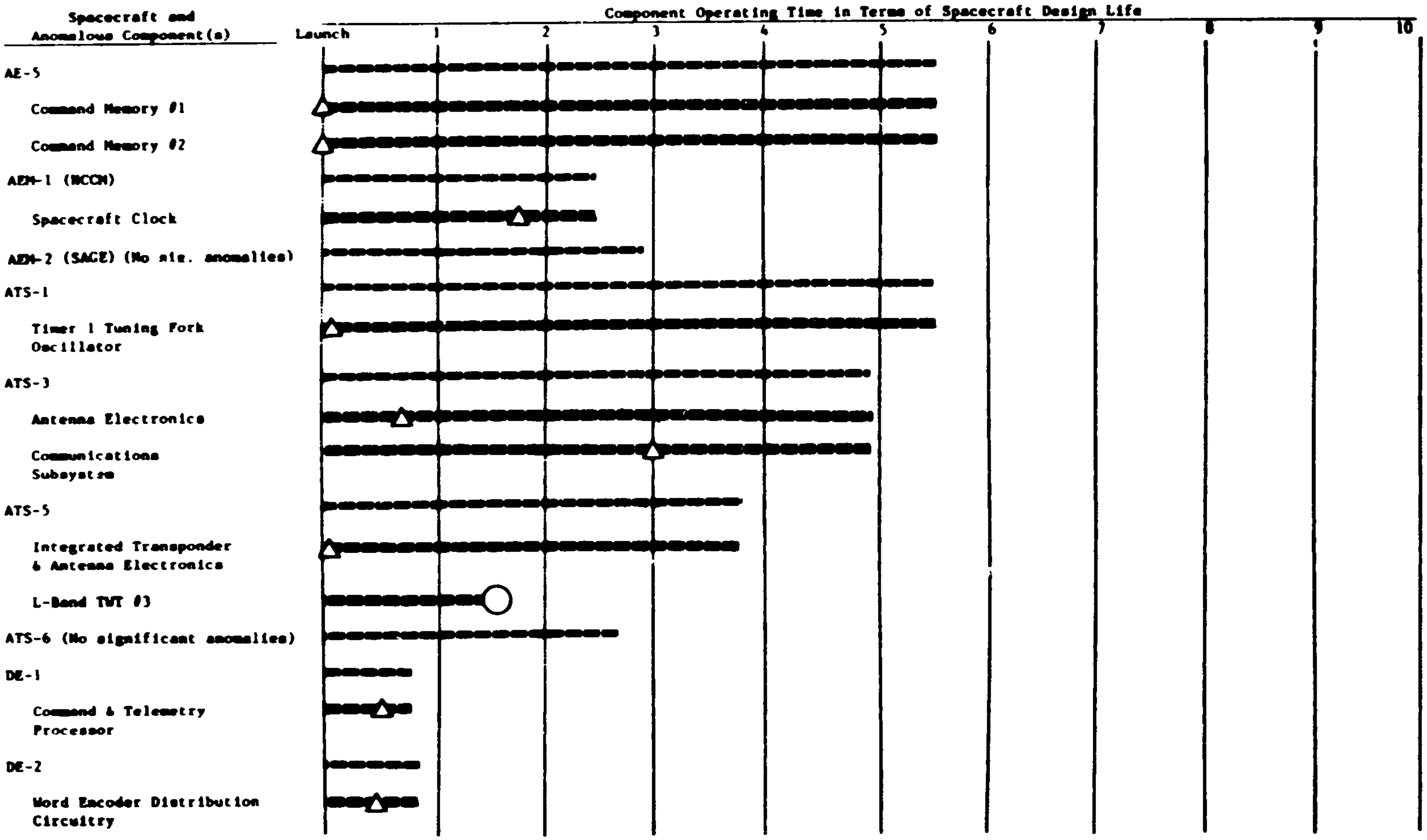
TIMING, CONTROL, AND COMMAND SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates a significant anomaly that is not a failure.

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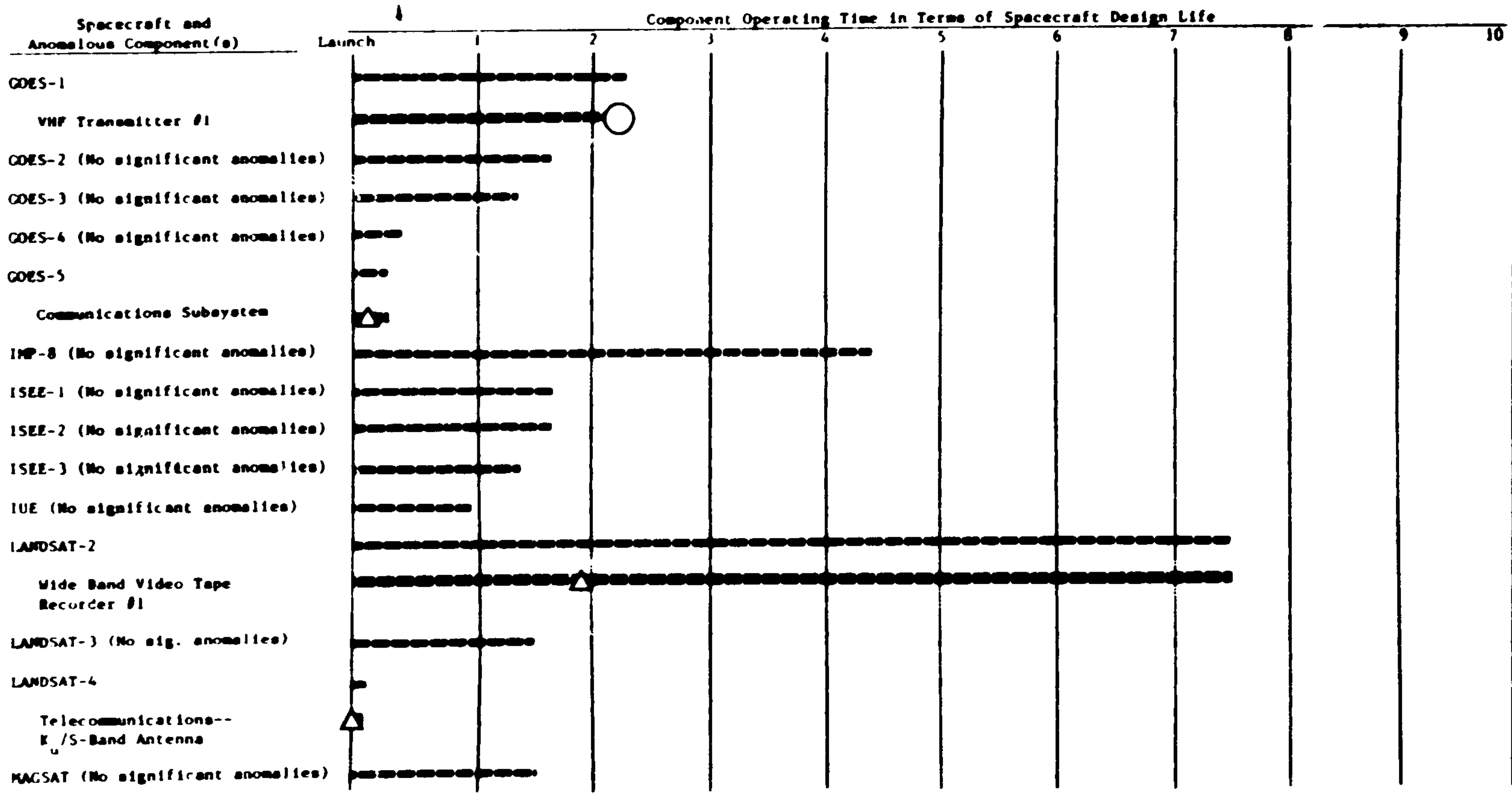
TIMING, CONTROL AND COMMAND SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates a significant anomaly that is not a failure.

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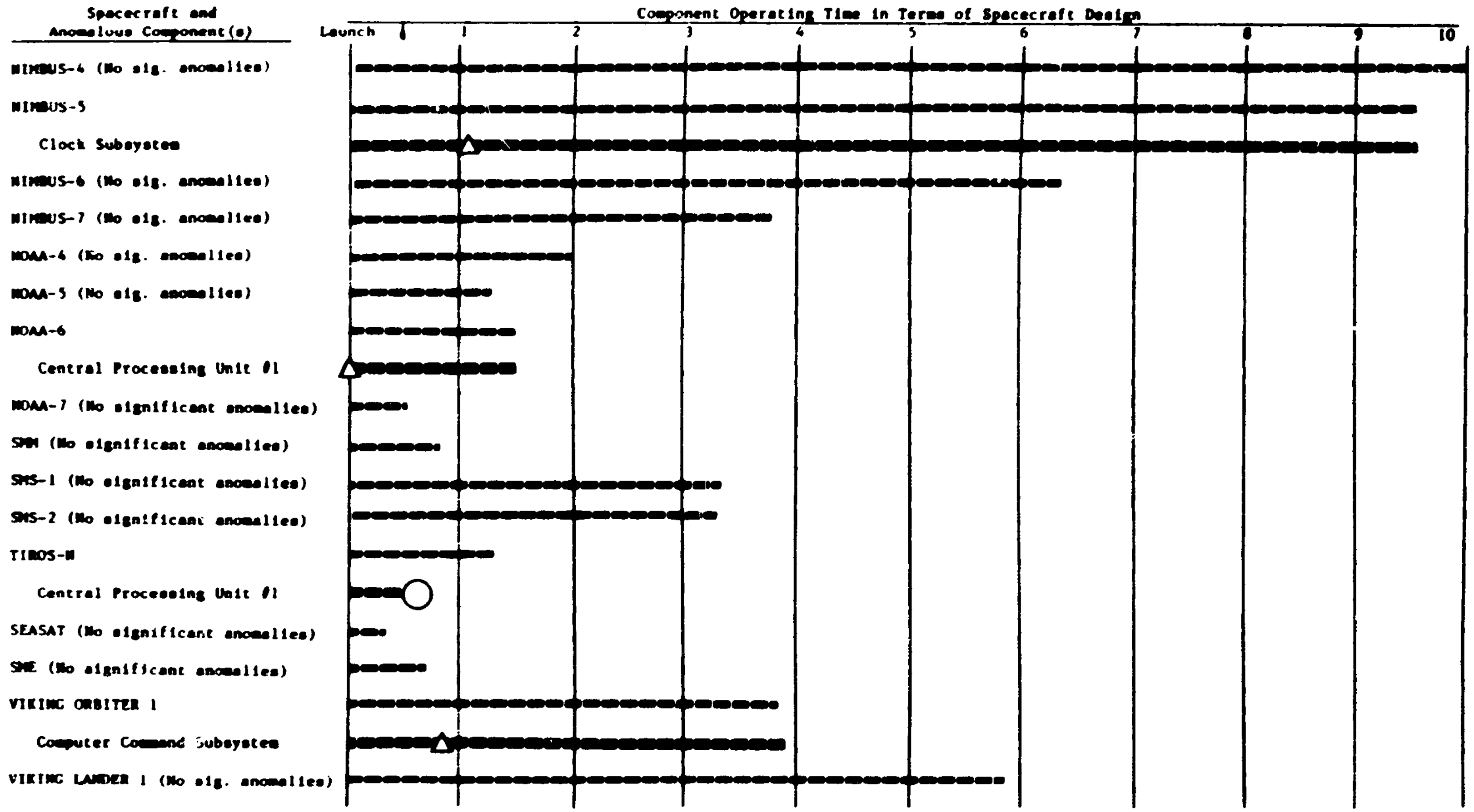
TIMING, CONTROL AND COMMAND SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

△ indicates a significant anomaly that is not a failure.

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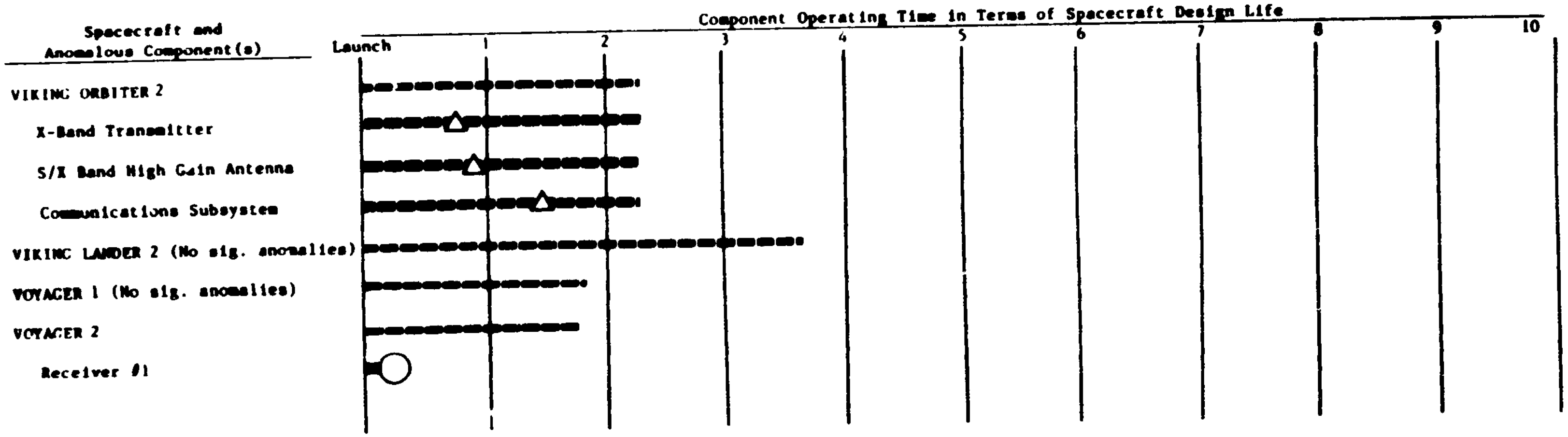
TIMING, CONTROL AND COMMAND SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Concluded)



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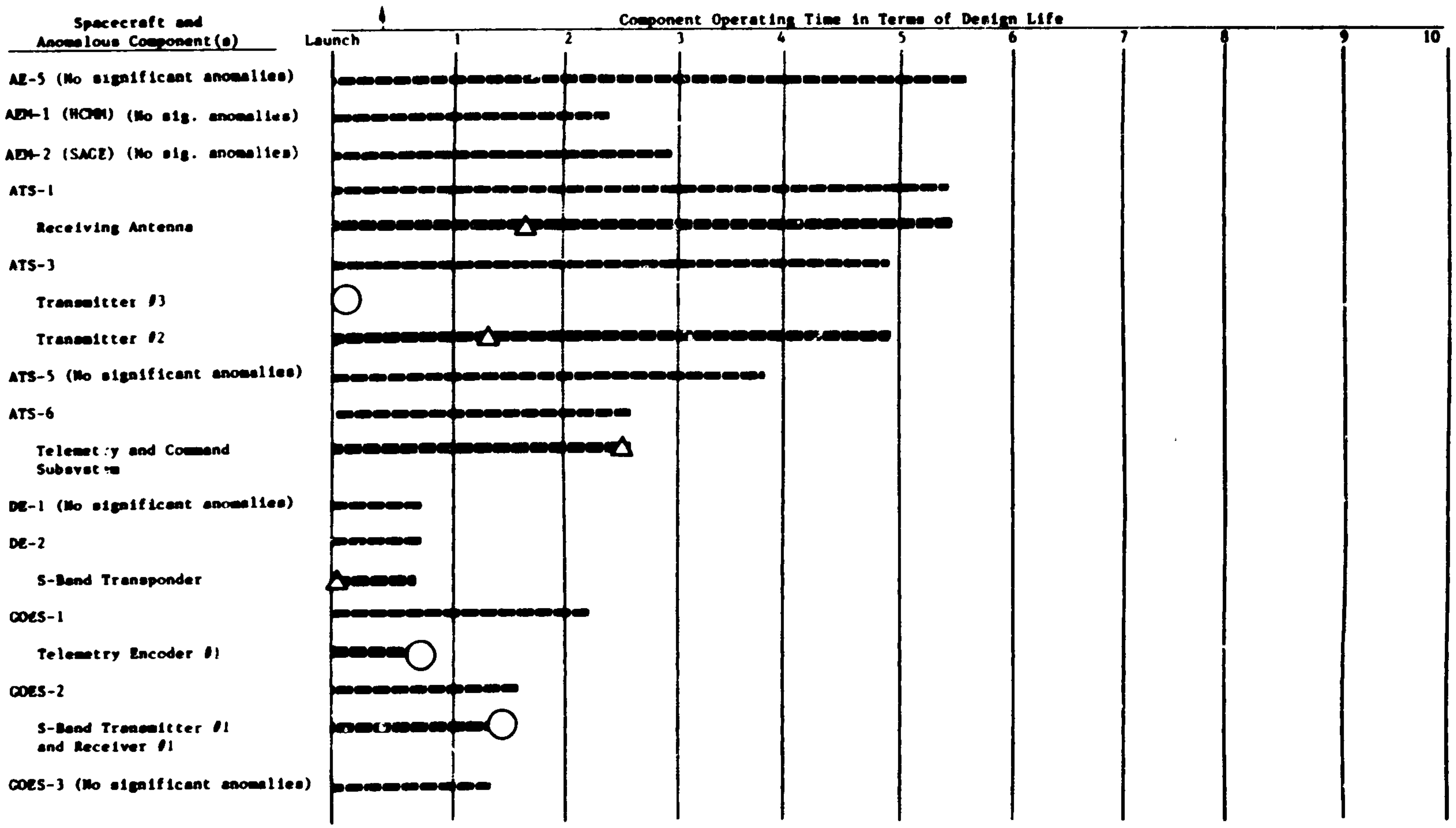
TELEMETRY AND DATA HANDLING SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES



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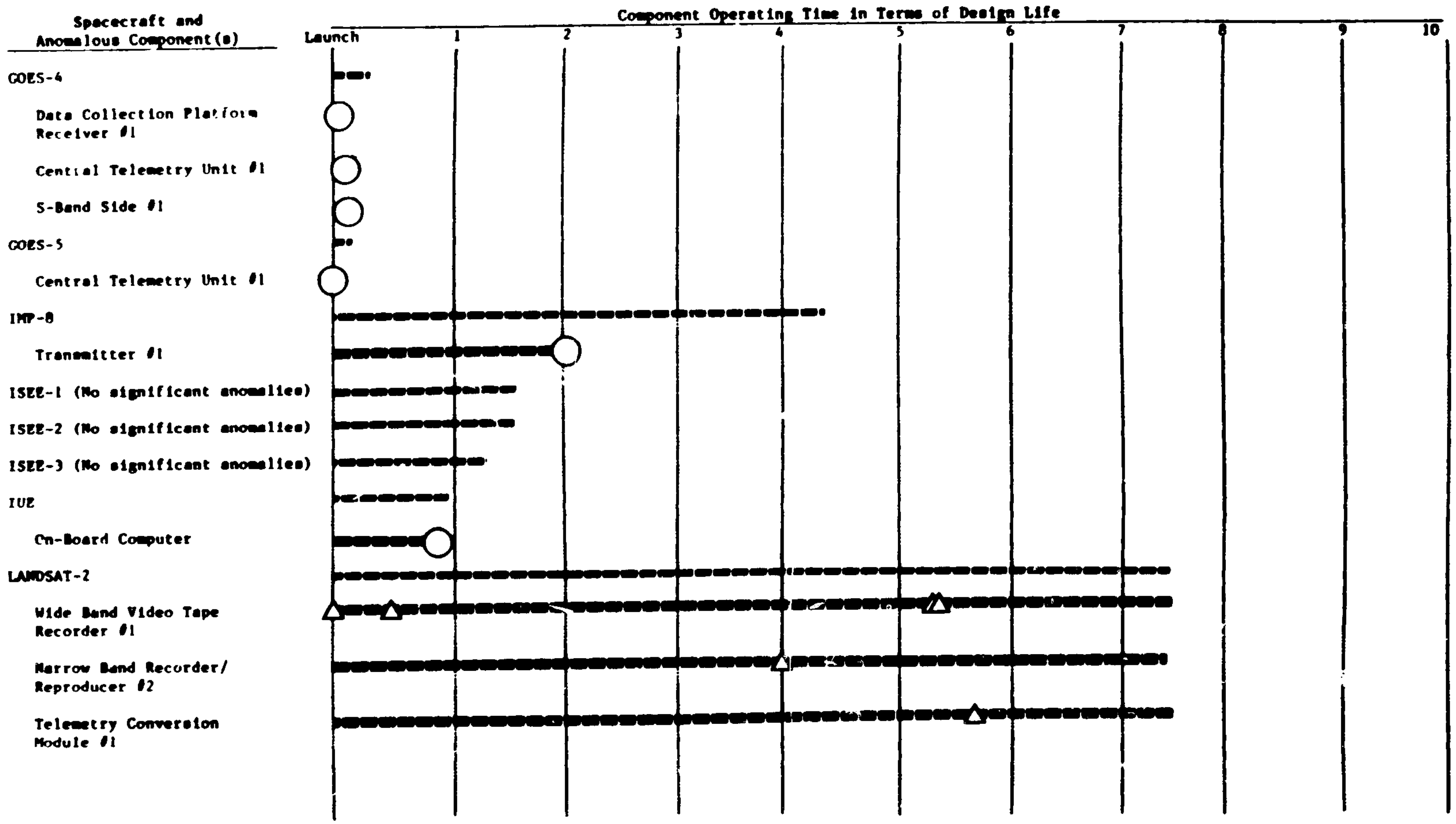
TELEMETRY AND DATA HANDLING SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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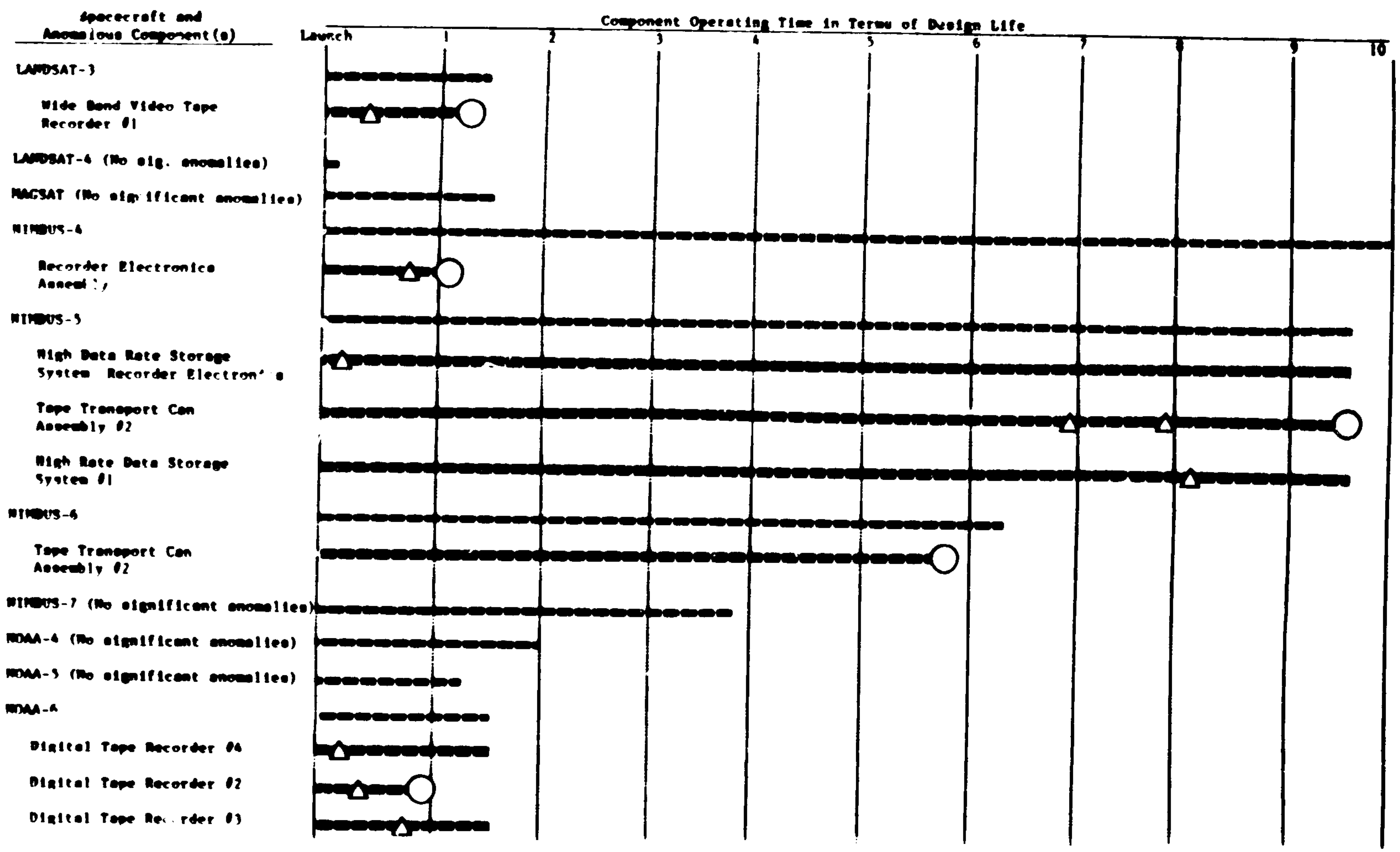
TELEMETRY AND DATA HANDLING SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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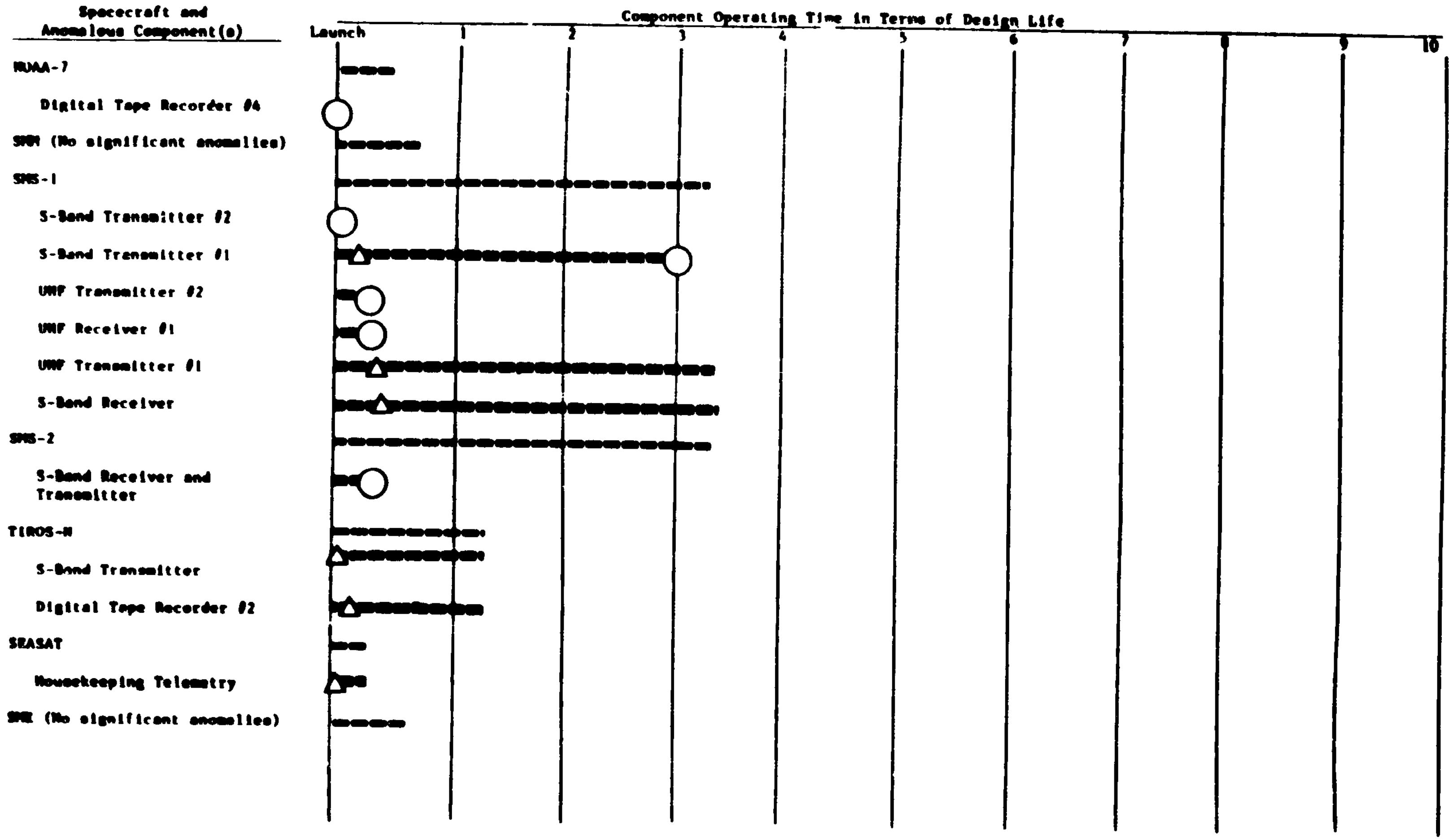
TELEMETRY AND DATA HANDLING SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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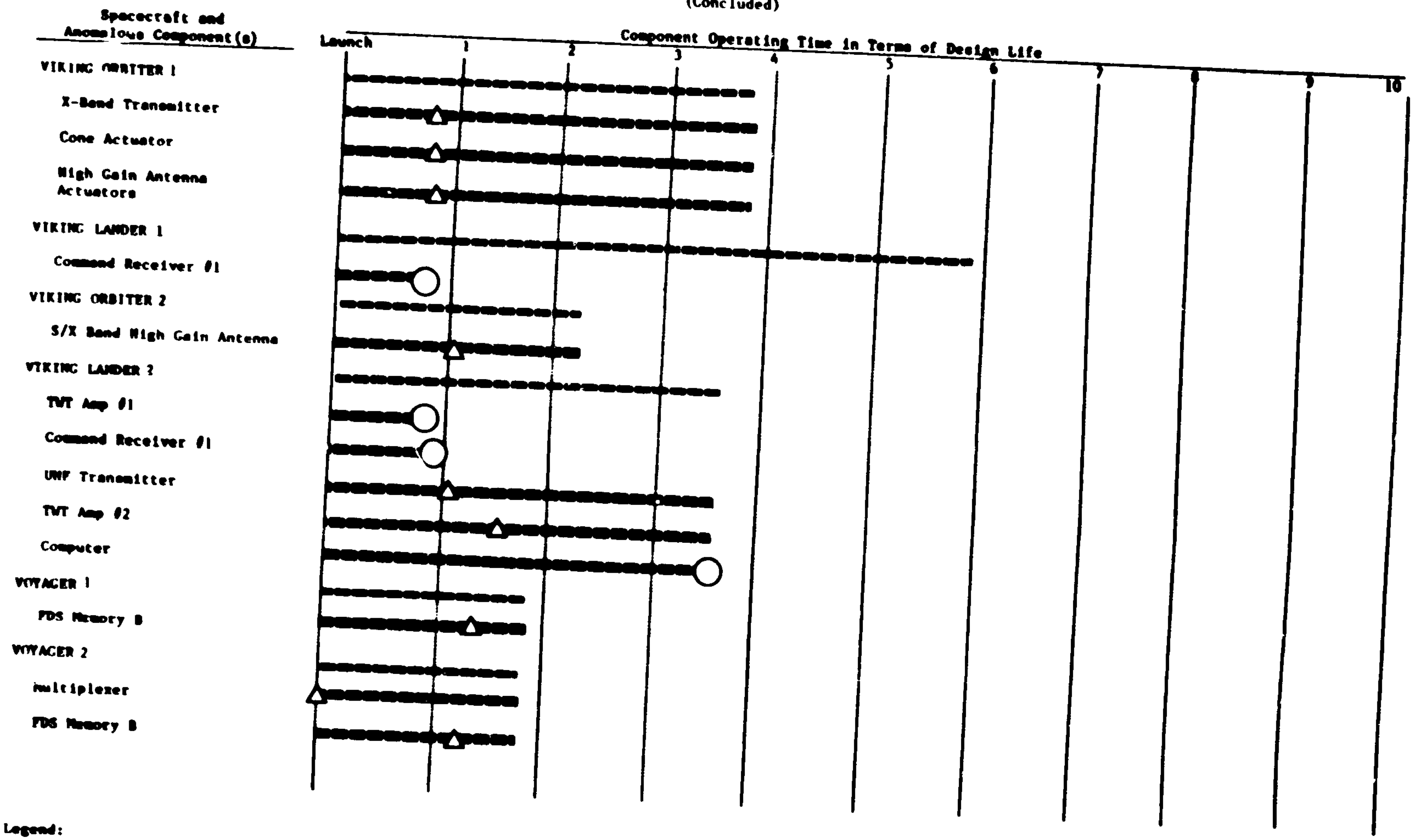
TELEMETRY AND DATA HANDLING SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Concluded)



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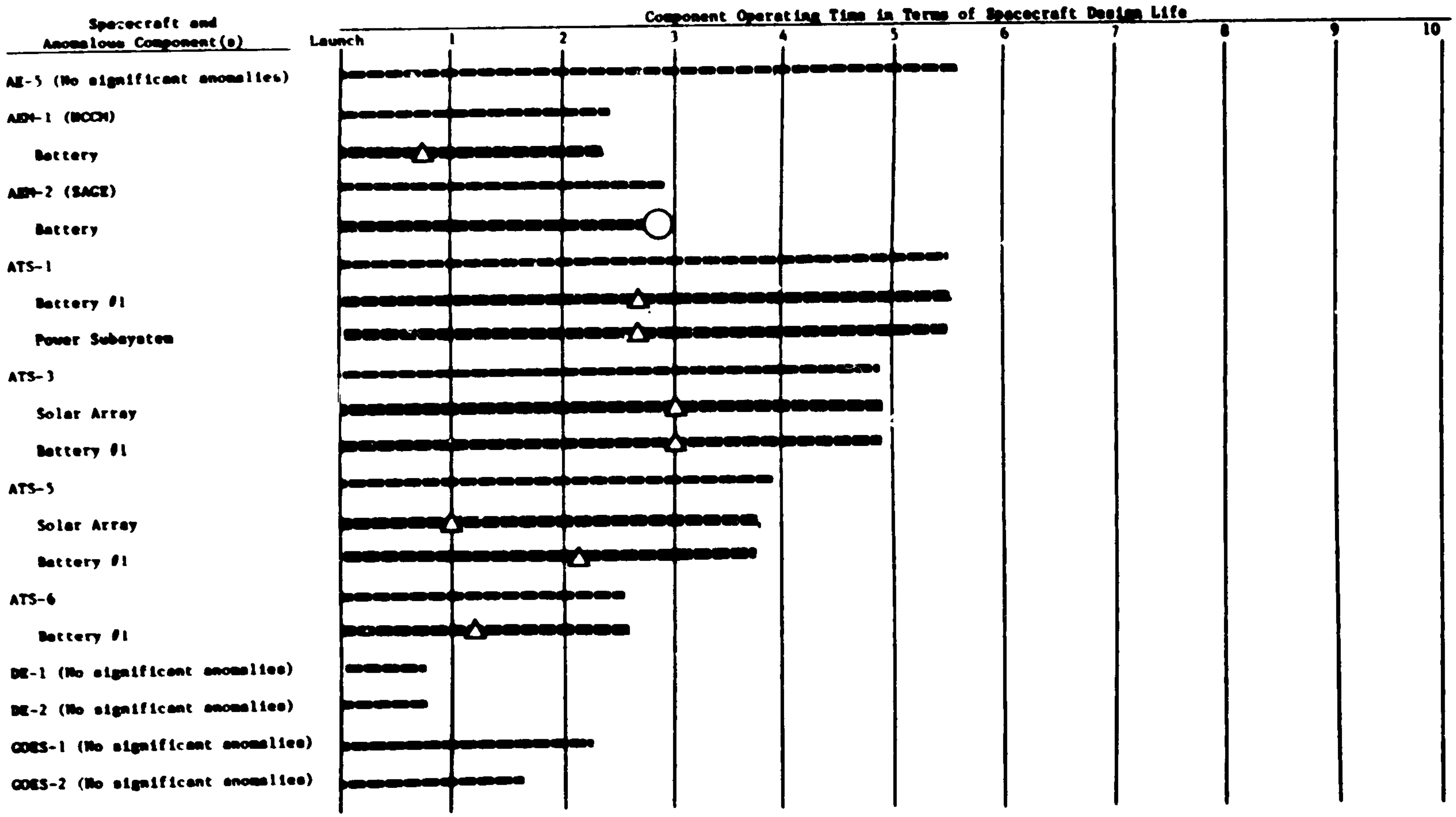
POWER SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES



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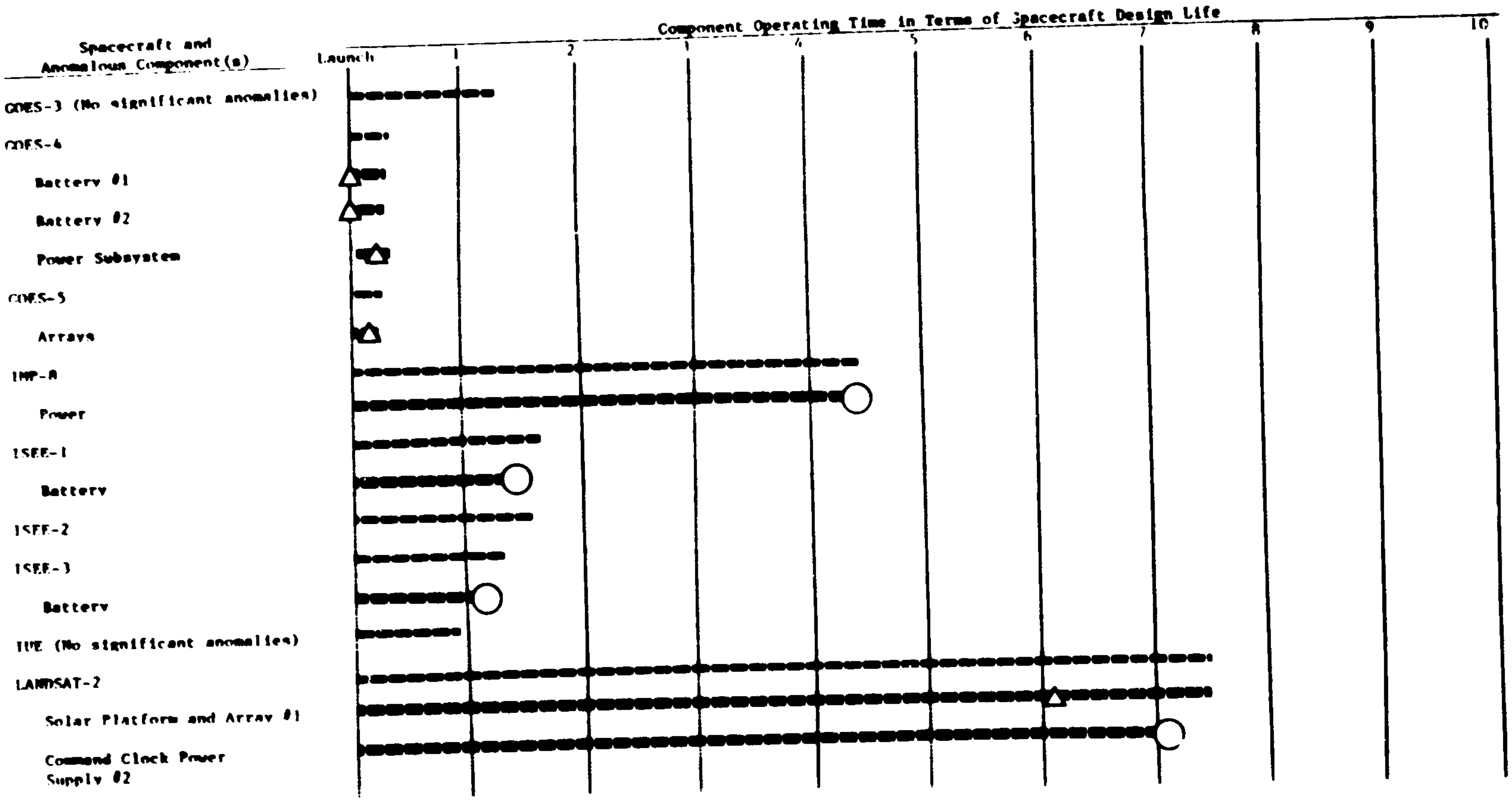
POWER SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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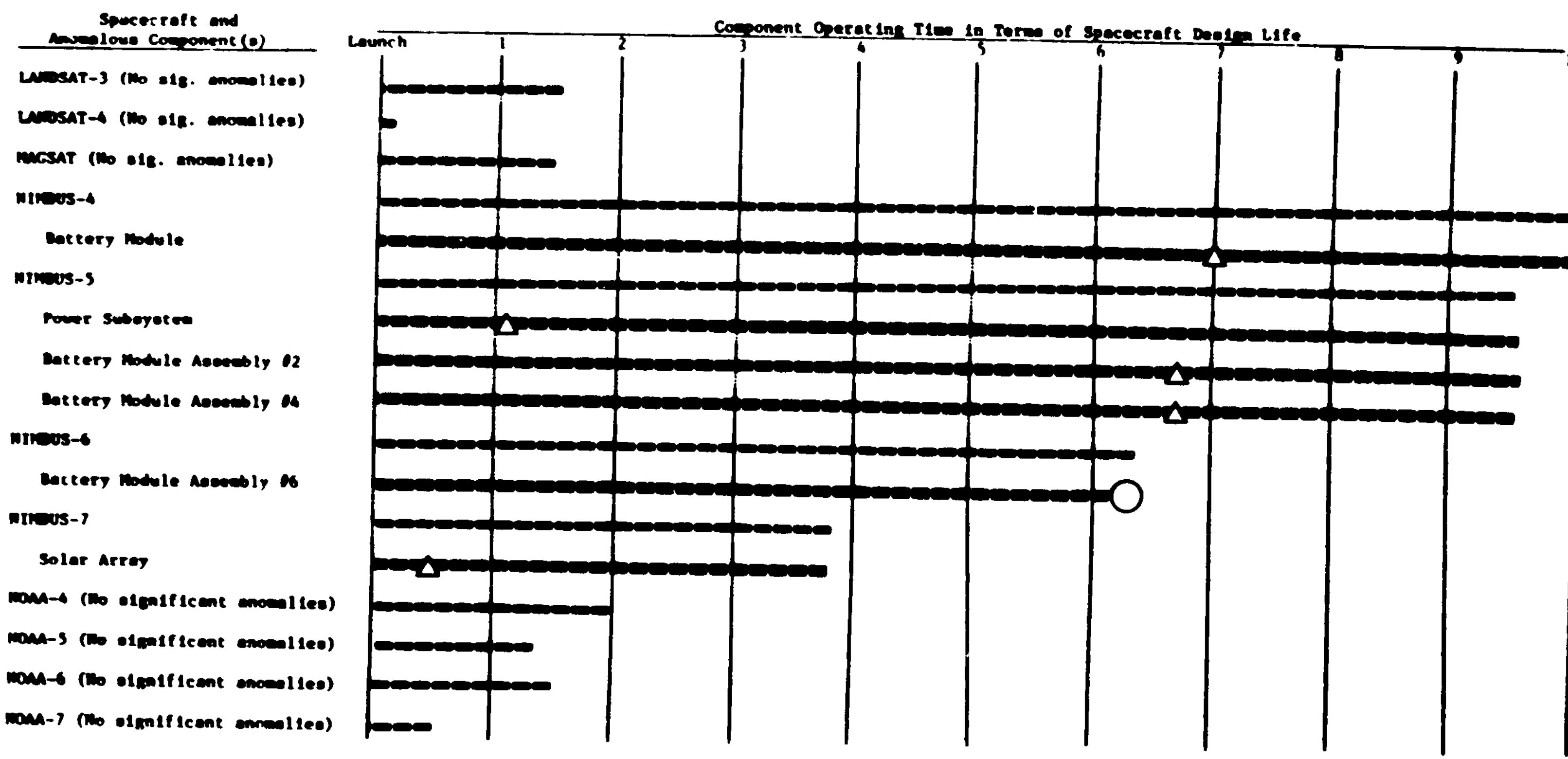
POWER SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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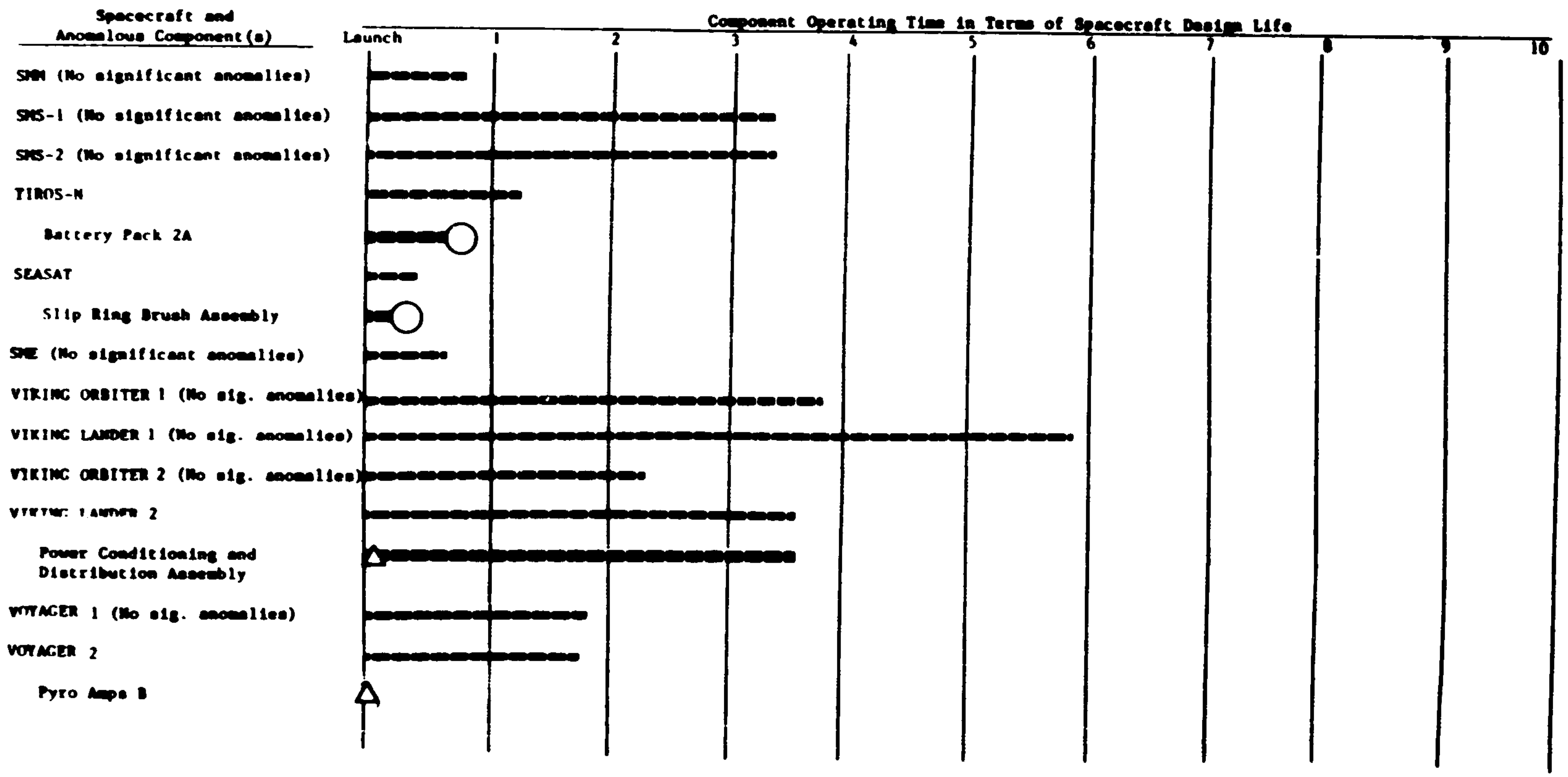
POWER SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Concluded)



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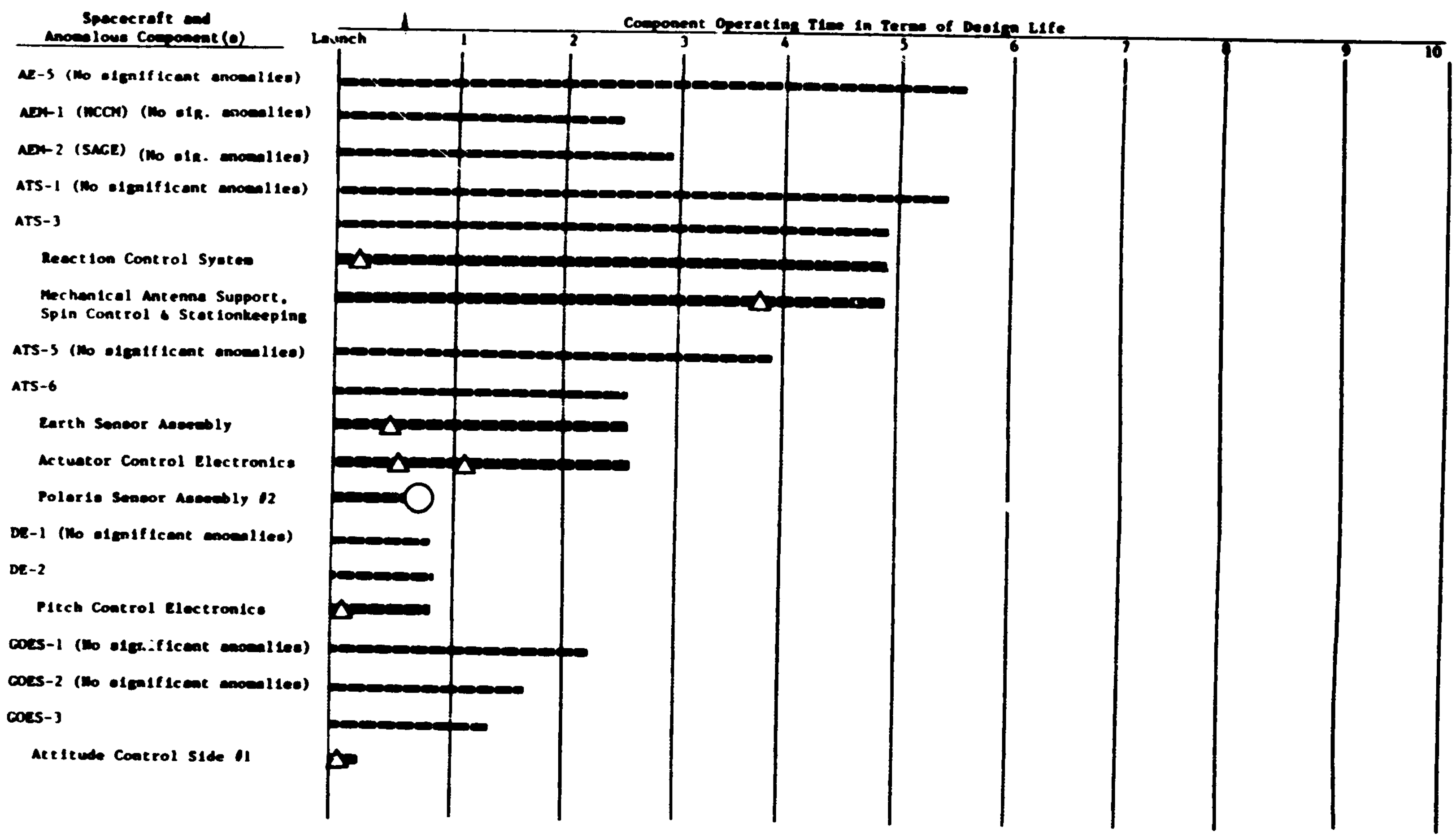
ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES



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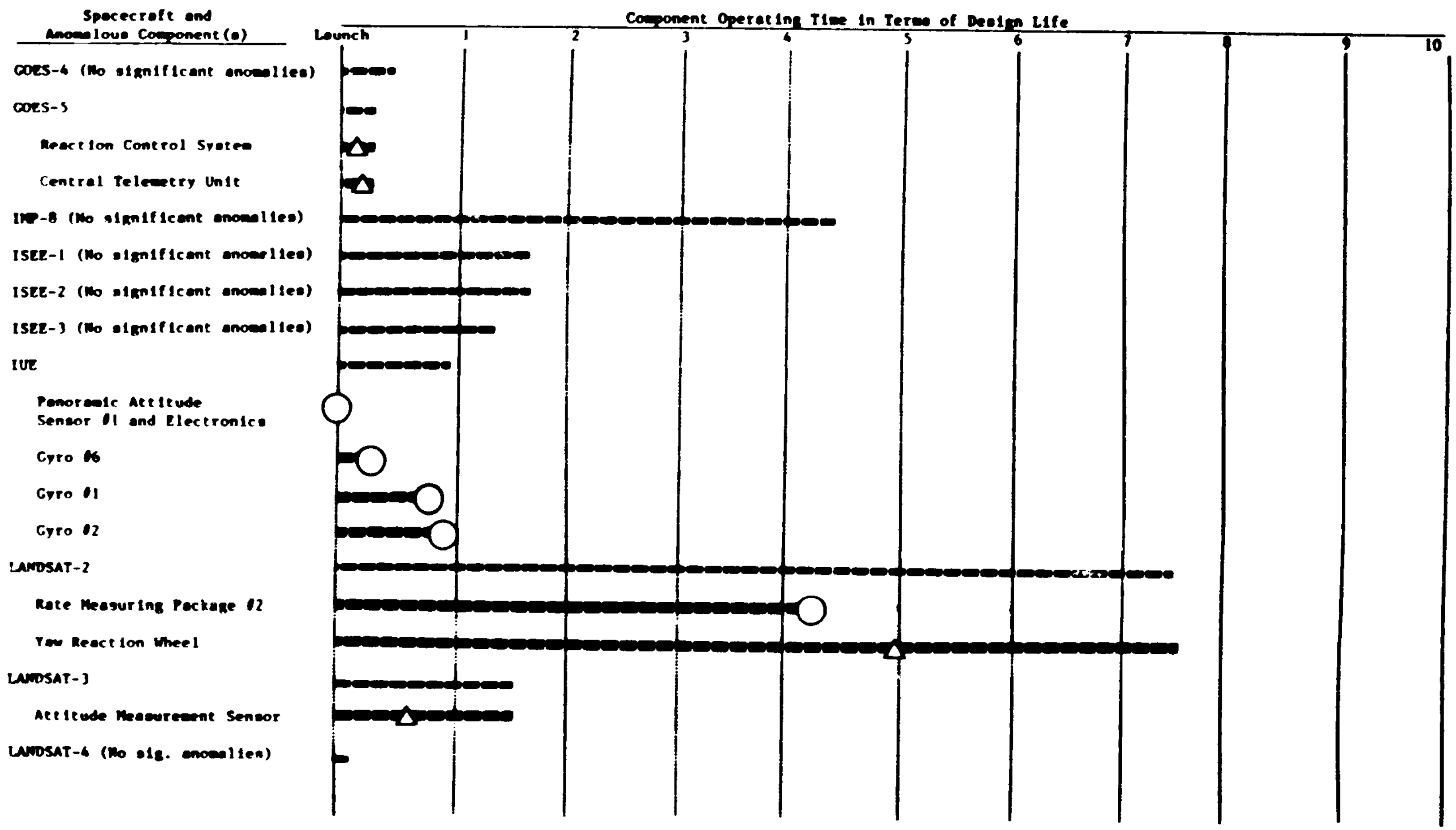
ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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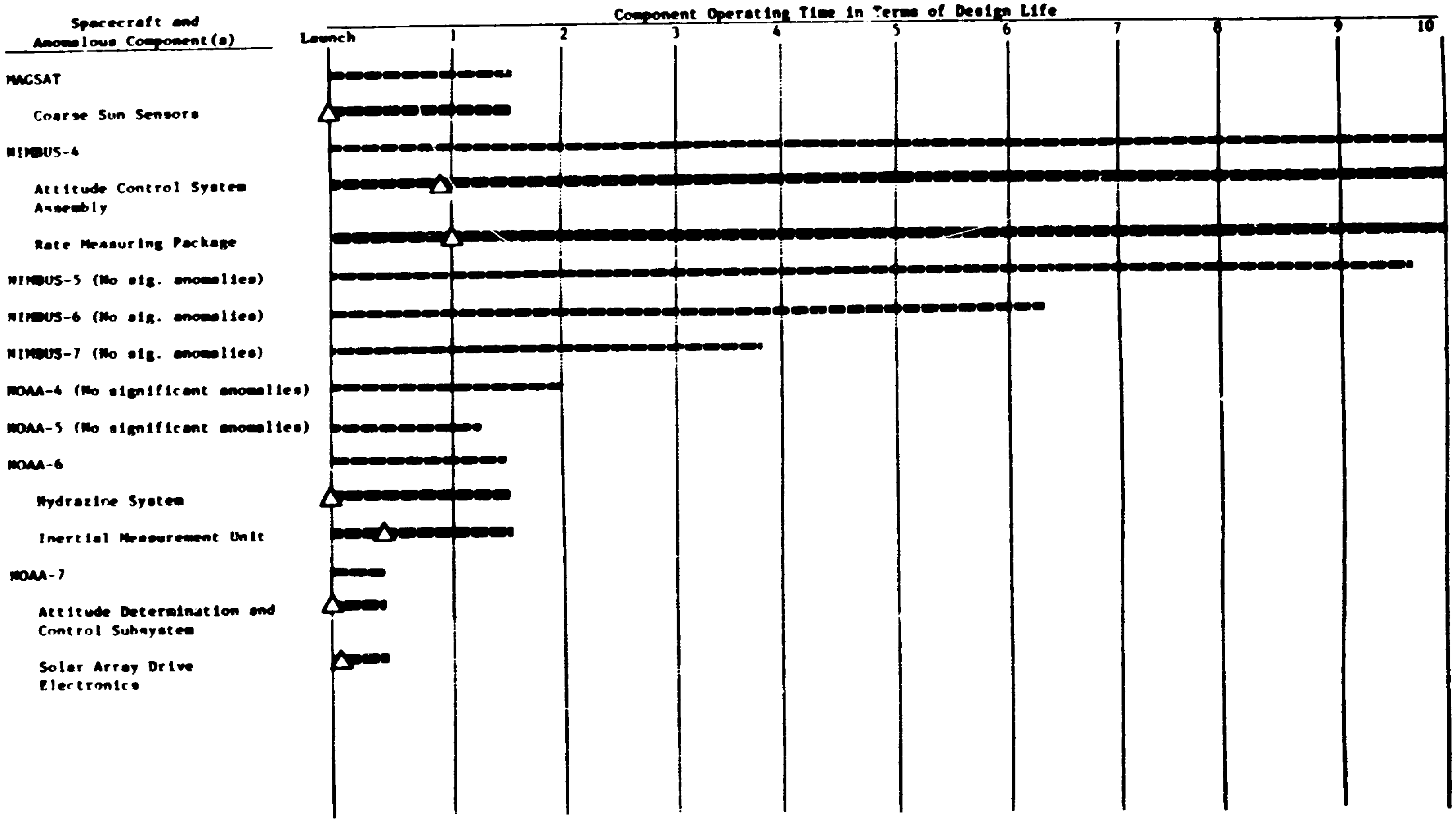
ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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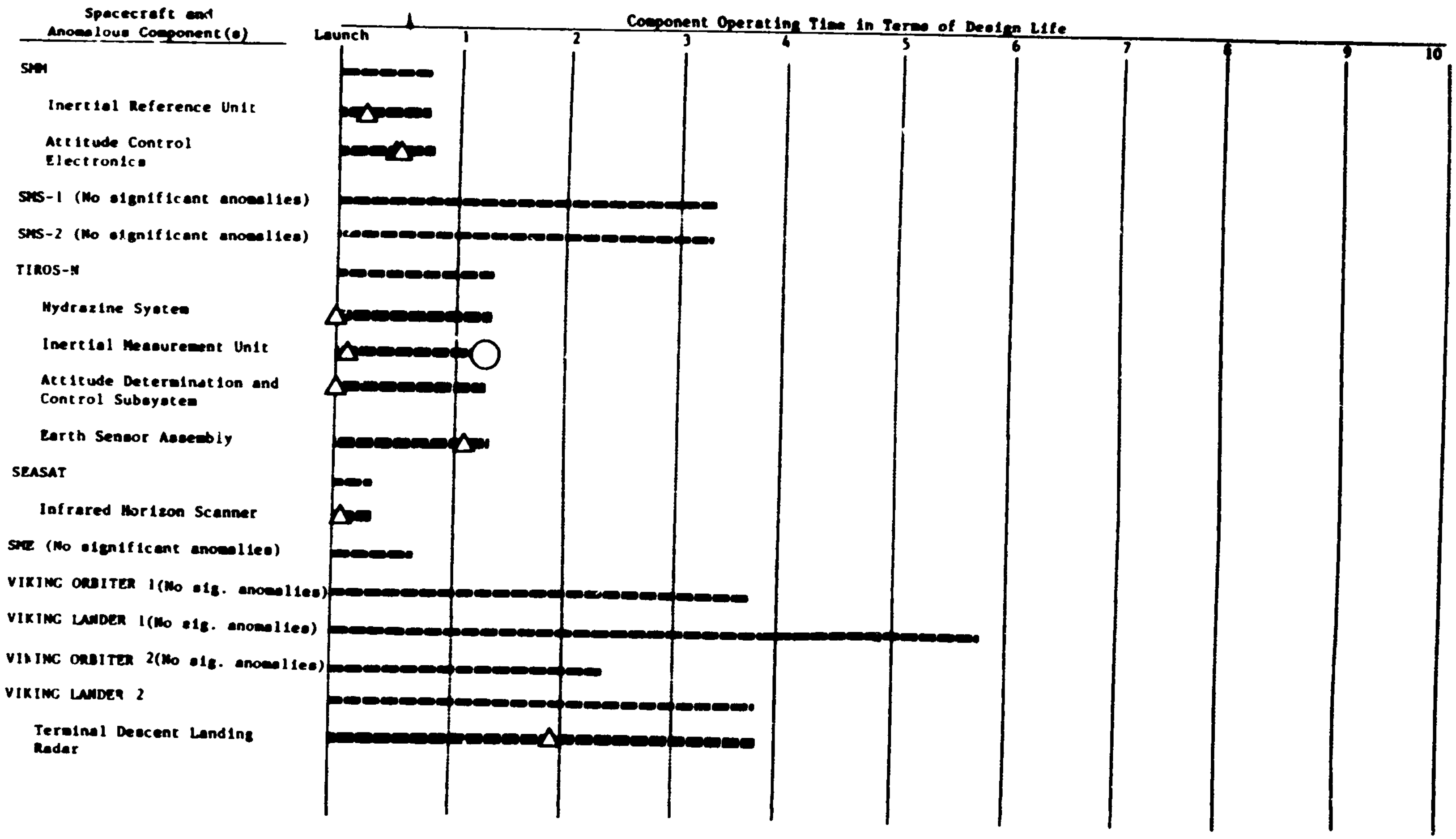
ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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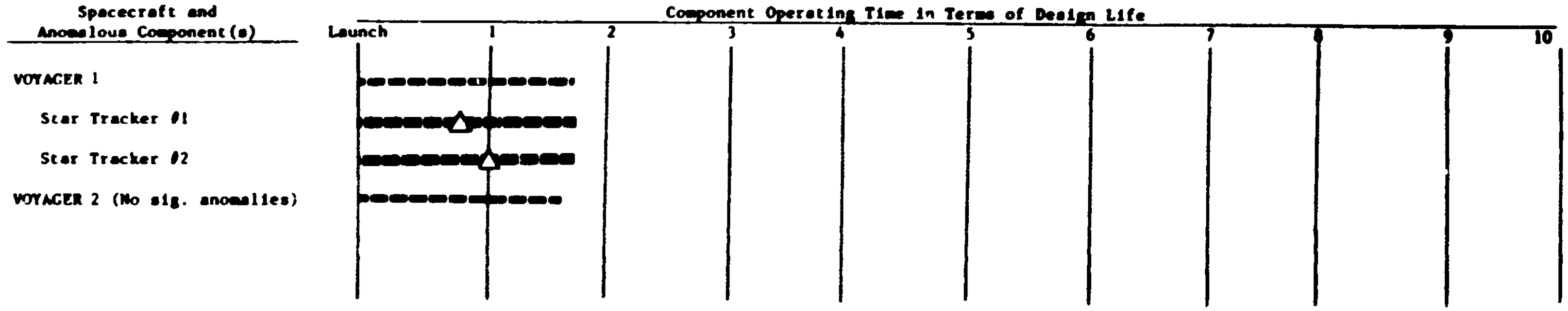
ATTITUDE CONTROL AND STABILIZATION SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Concluded)



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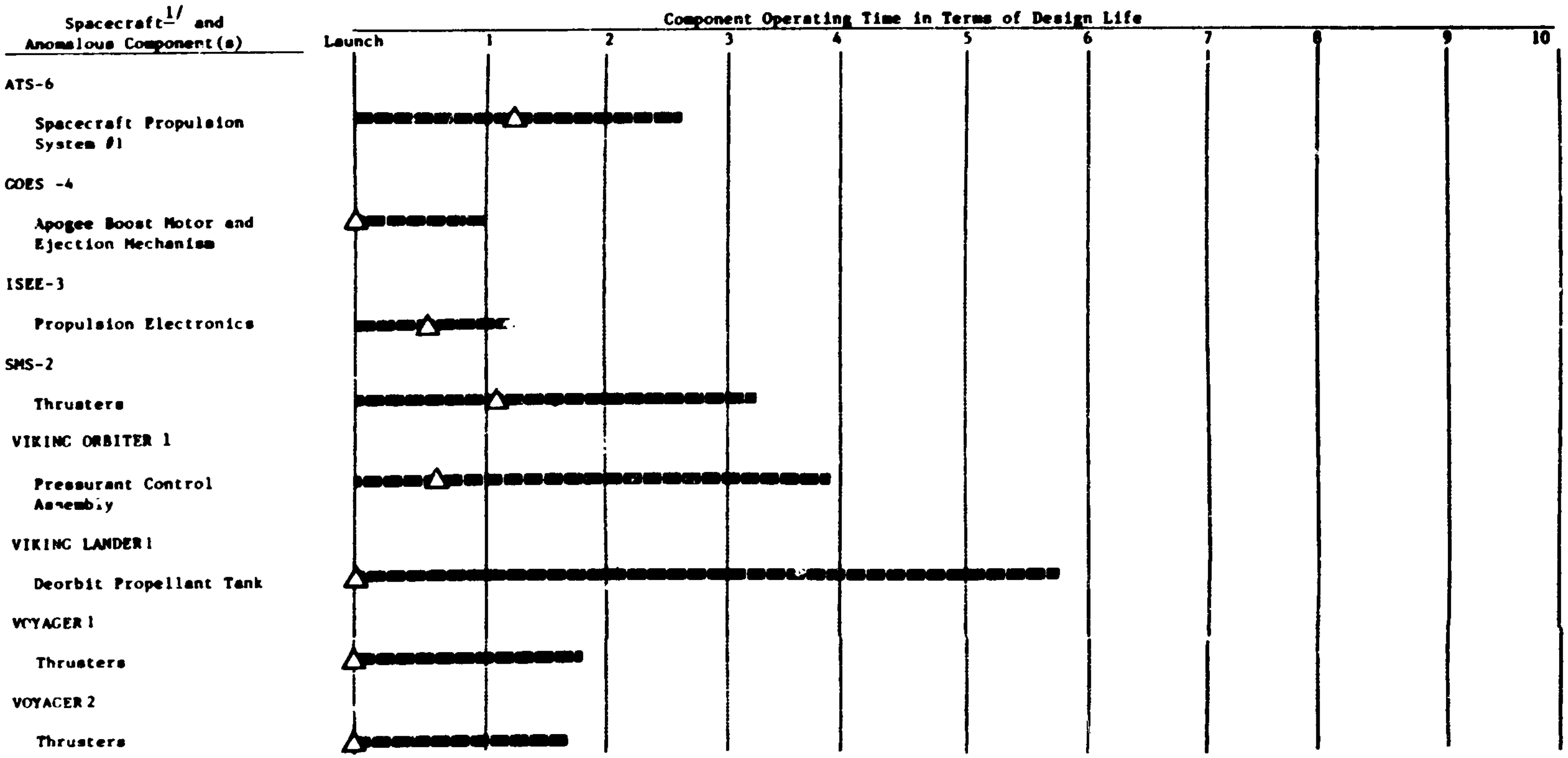
PROPULSION SUBSYSTEM
ANOMALIES AND PERFORMANCE SUMMARIES



Legend:

○ indicates that this anomaly is a failure, where failure is defined as the event that renders the subsystem and/or component unusable.

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1/ Only spacecraft with significant anomalies reported in the propulsion subsystem are listed.

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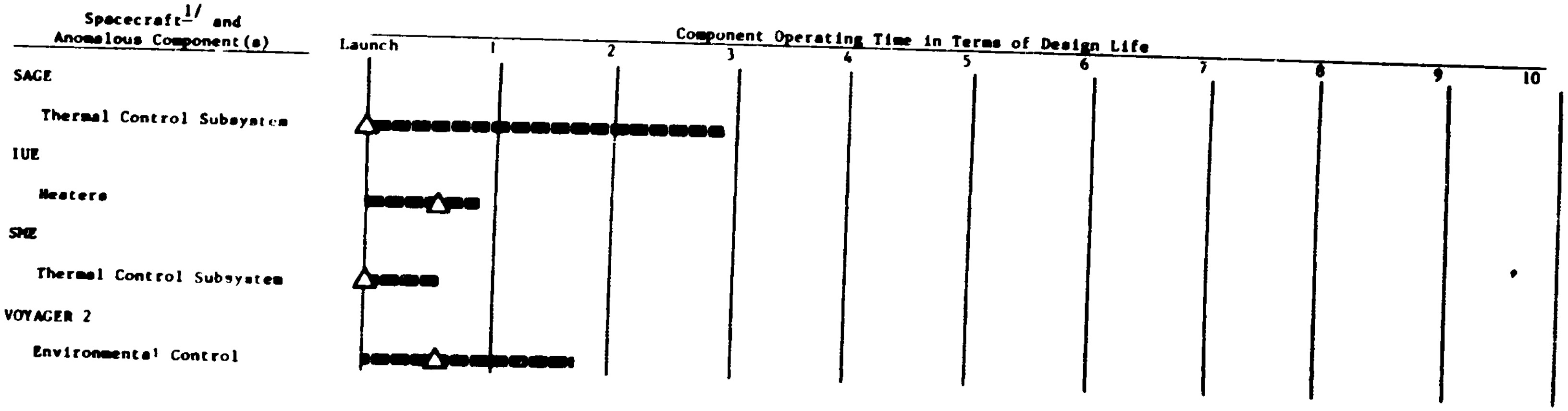
ENVIRONMENTAL CONTROL SUBSYSTEM
ANOMALIES AND PERFORMANCE SUMMARIES



Legend:

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1/ Only spacecraft with significant anomalies reported in the environmental control subsystem are listed.

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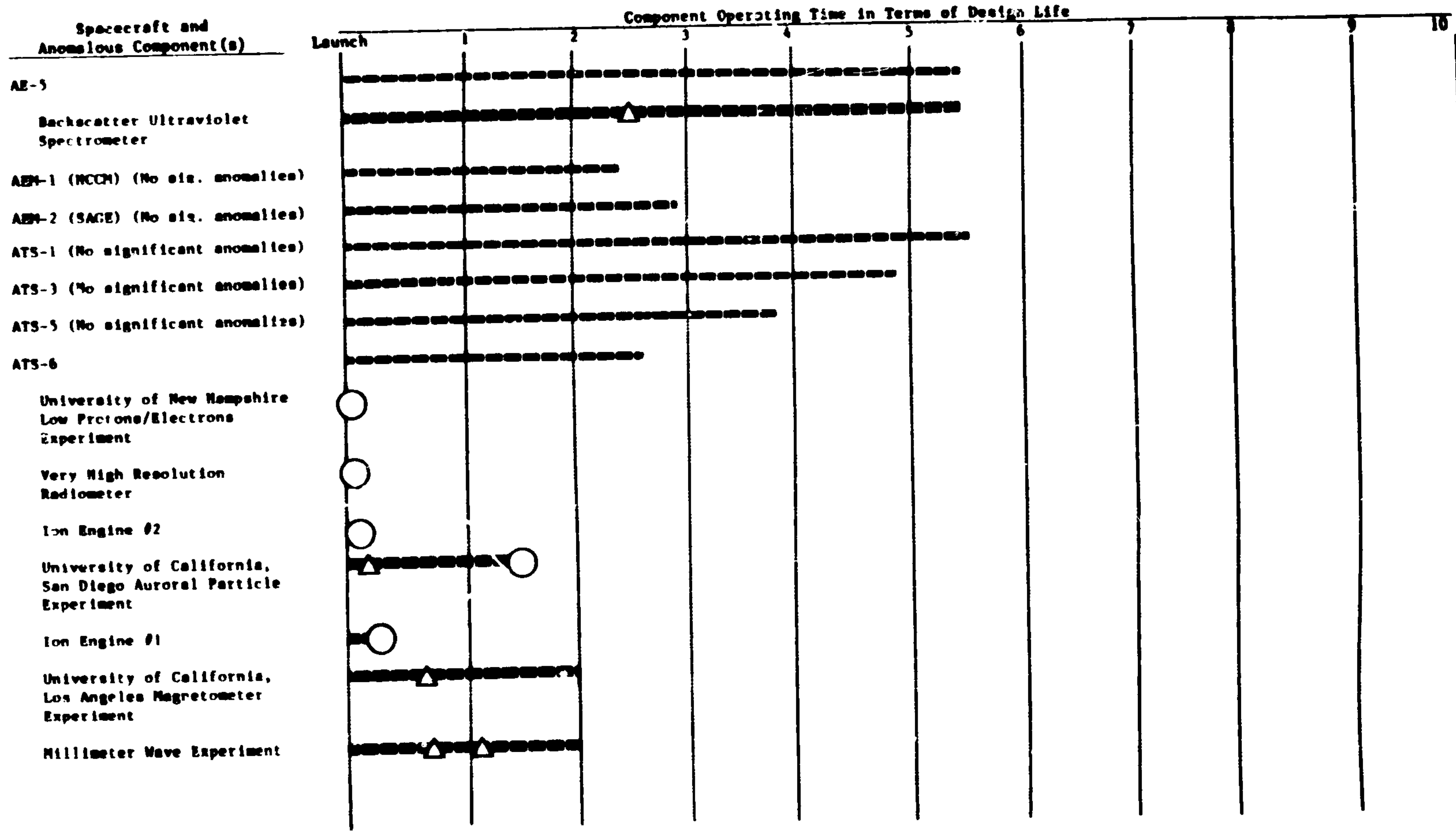
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES



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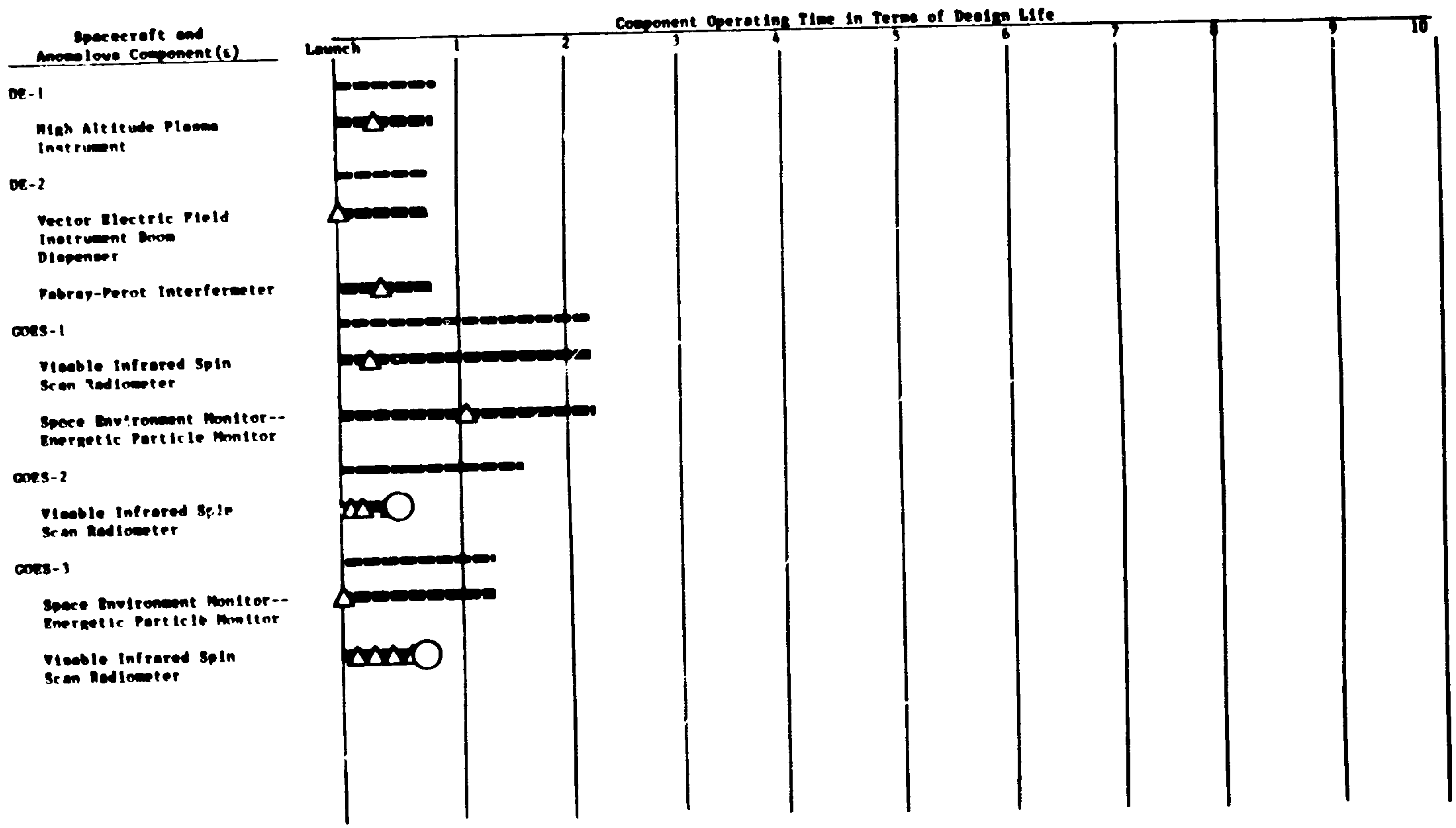
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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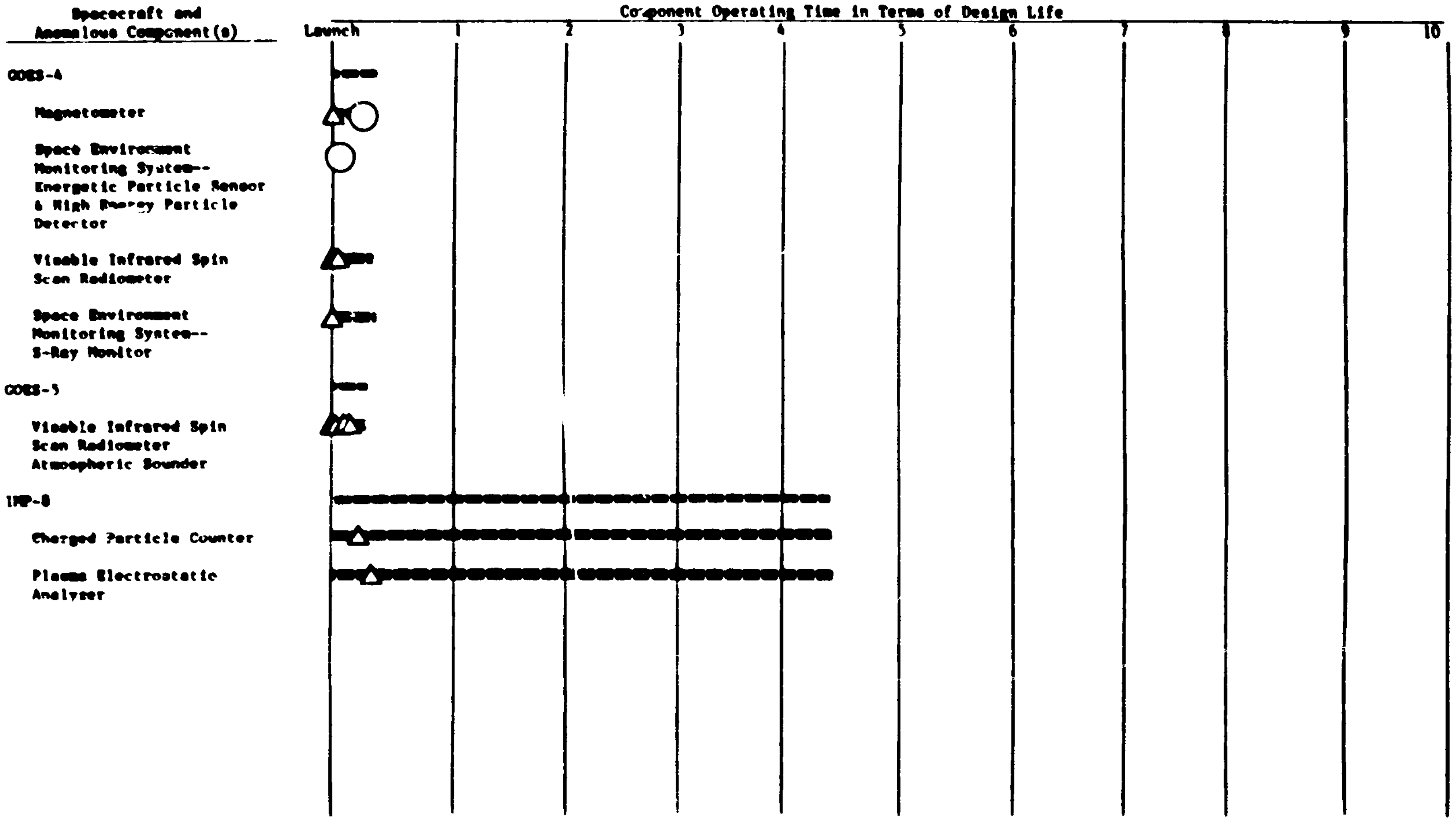
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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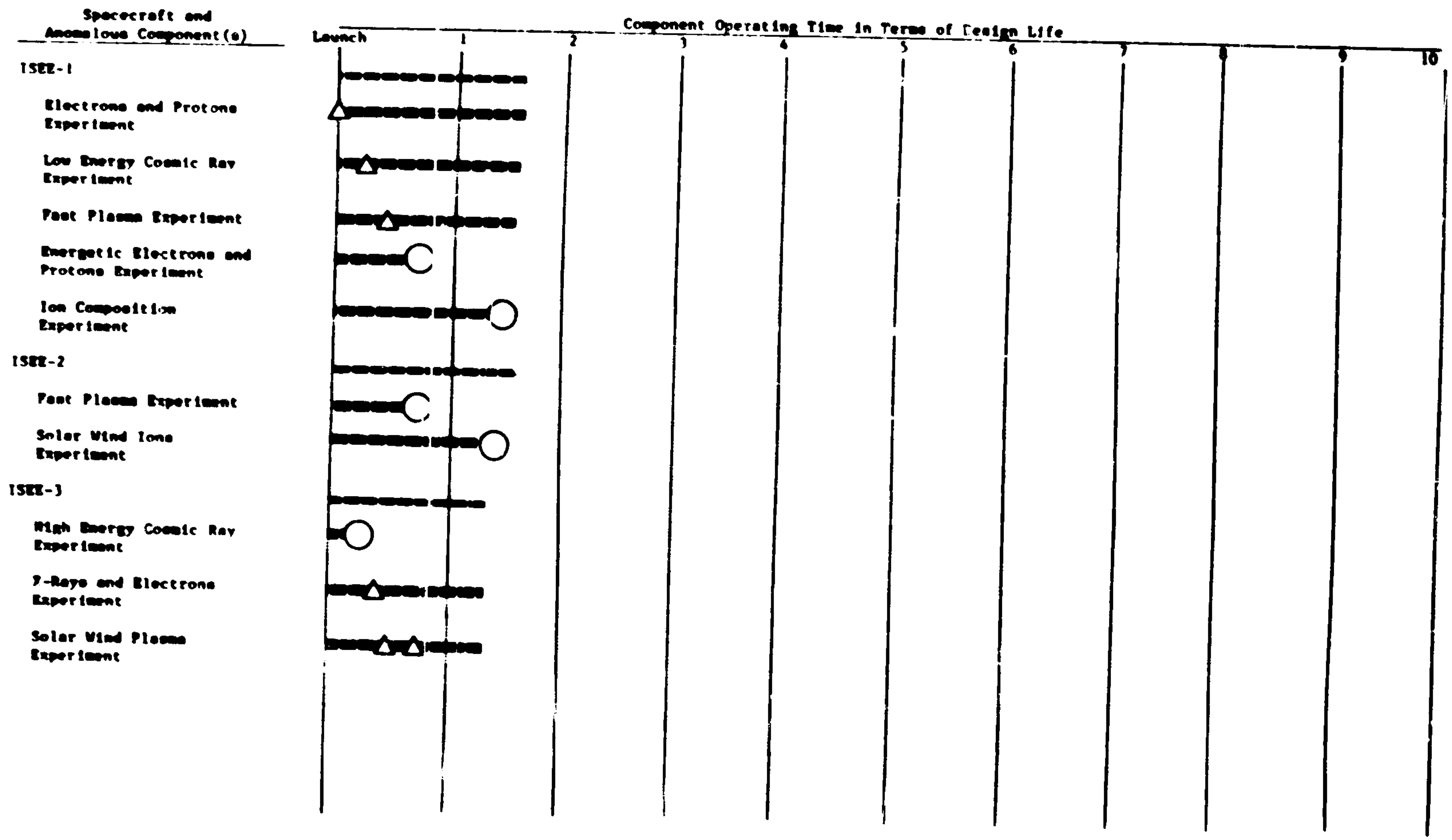
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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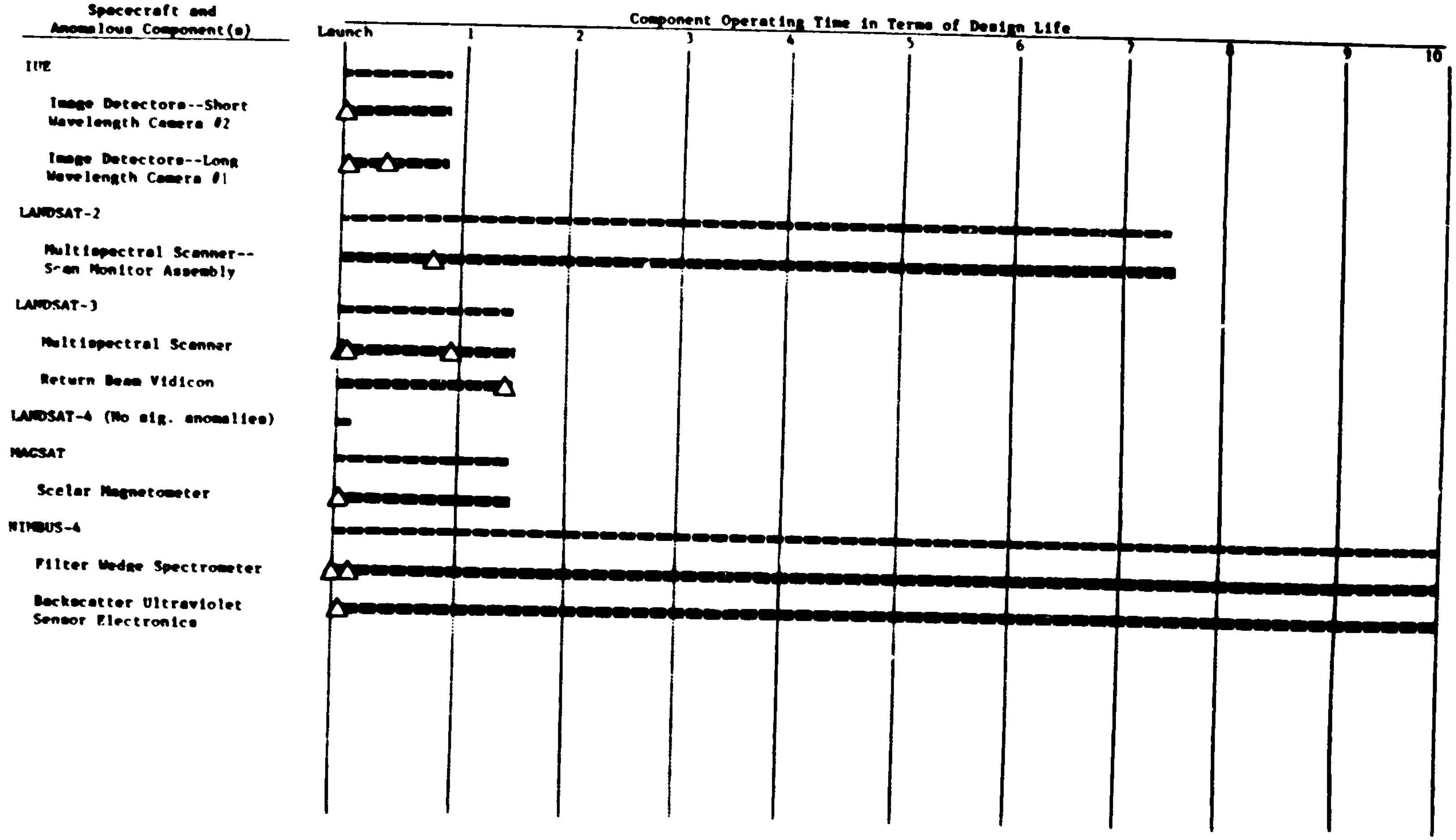
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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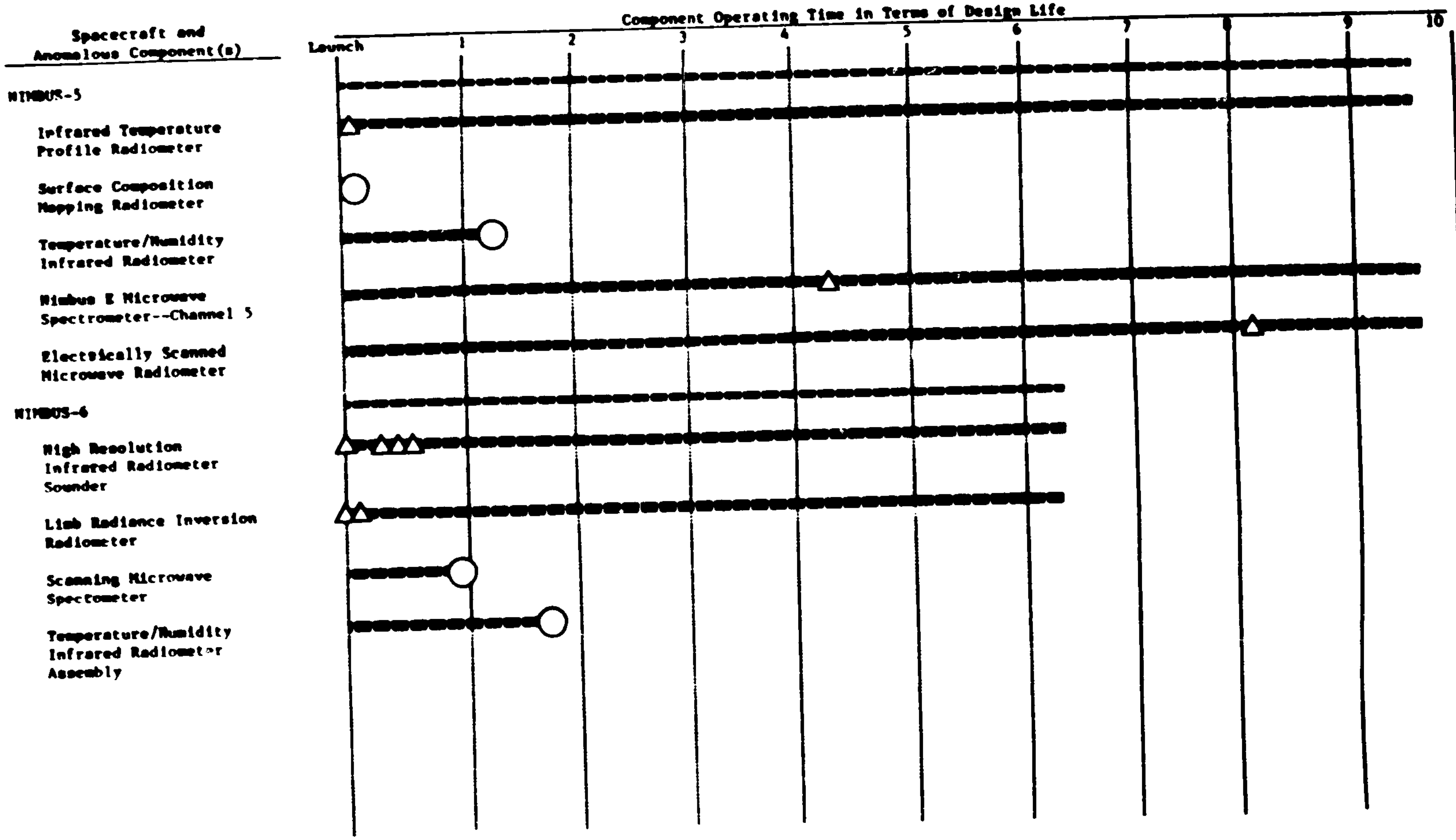
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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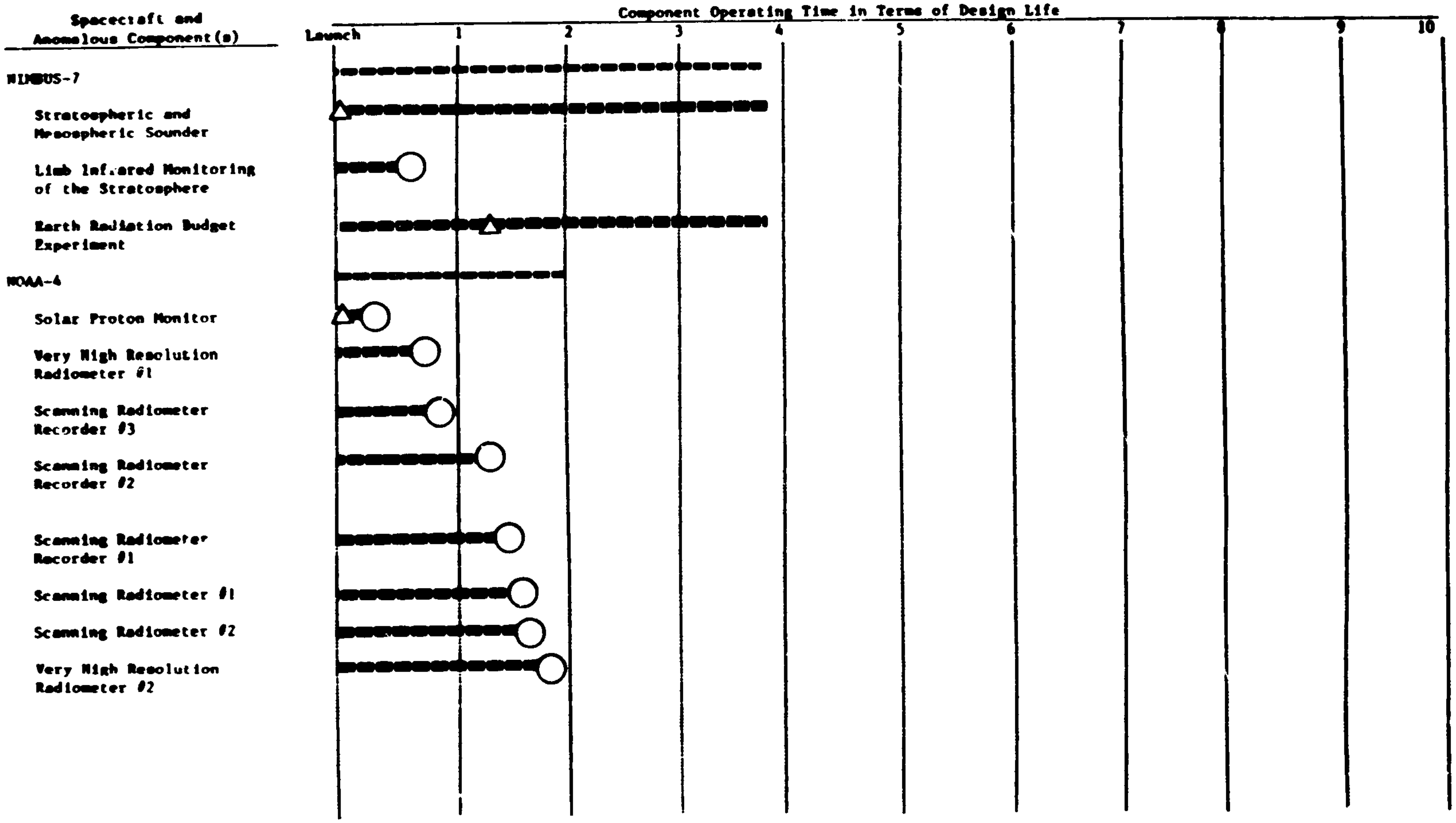
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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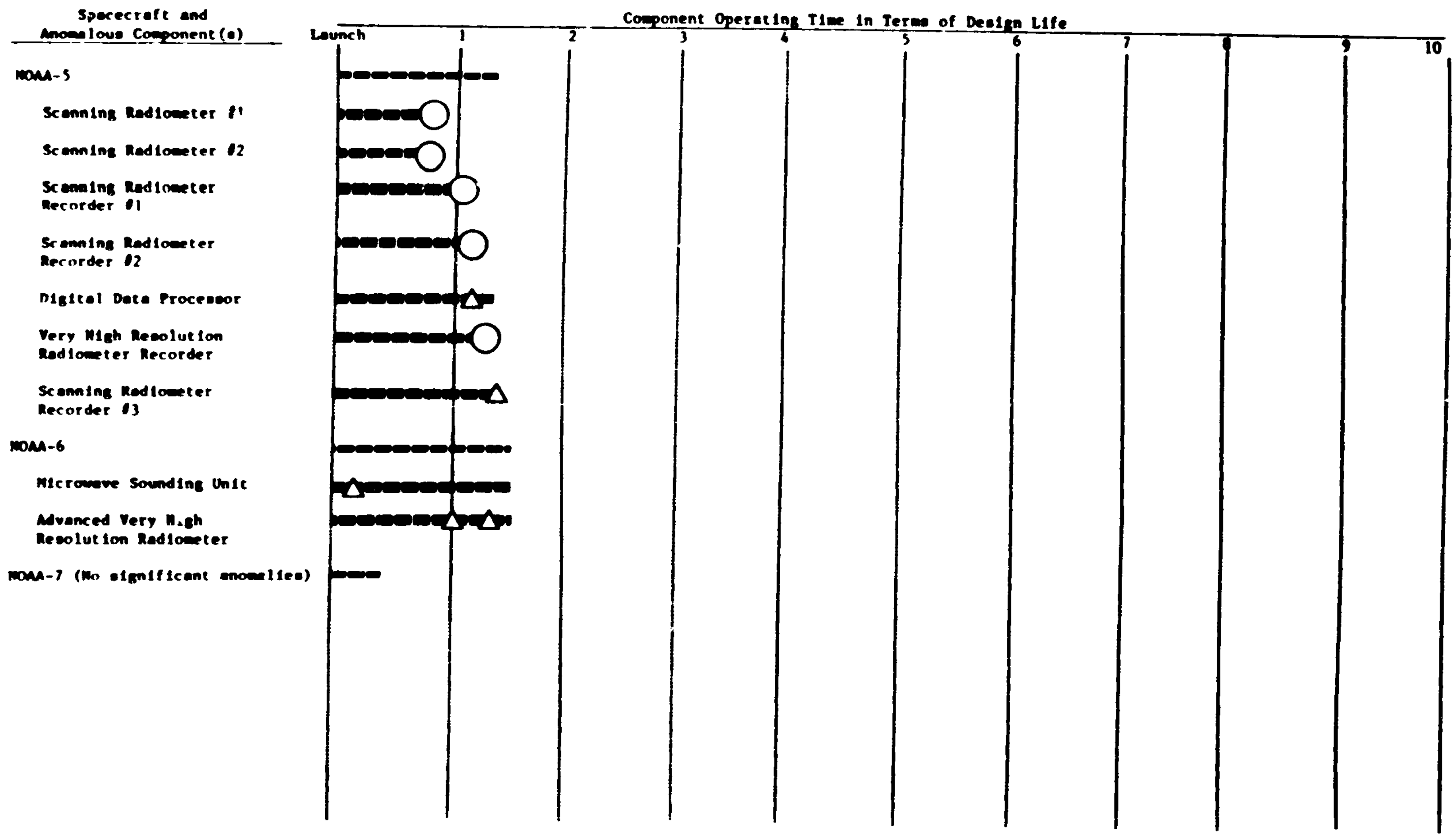
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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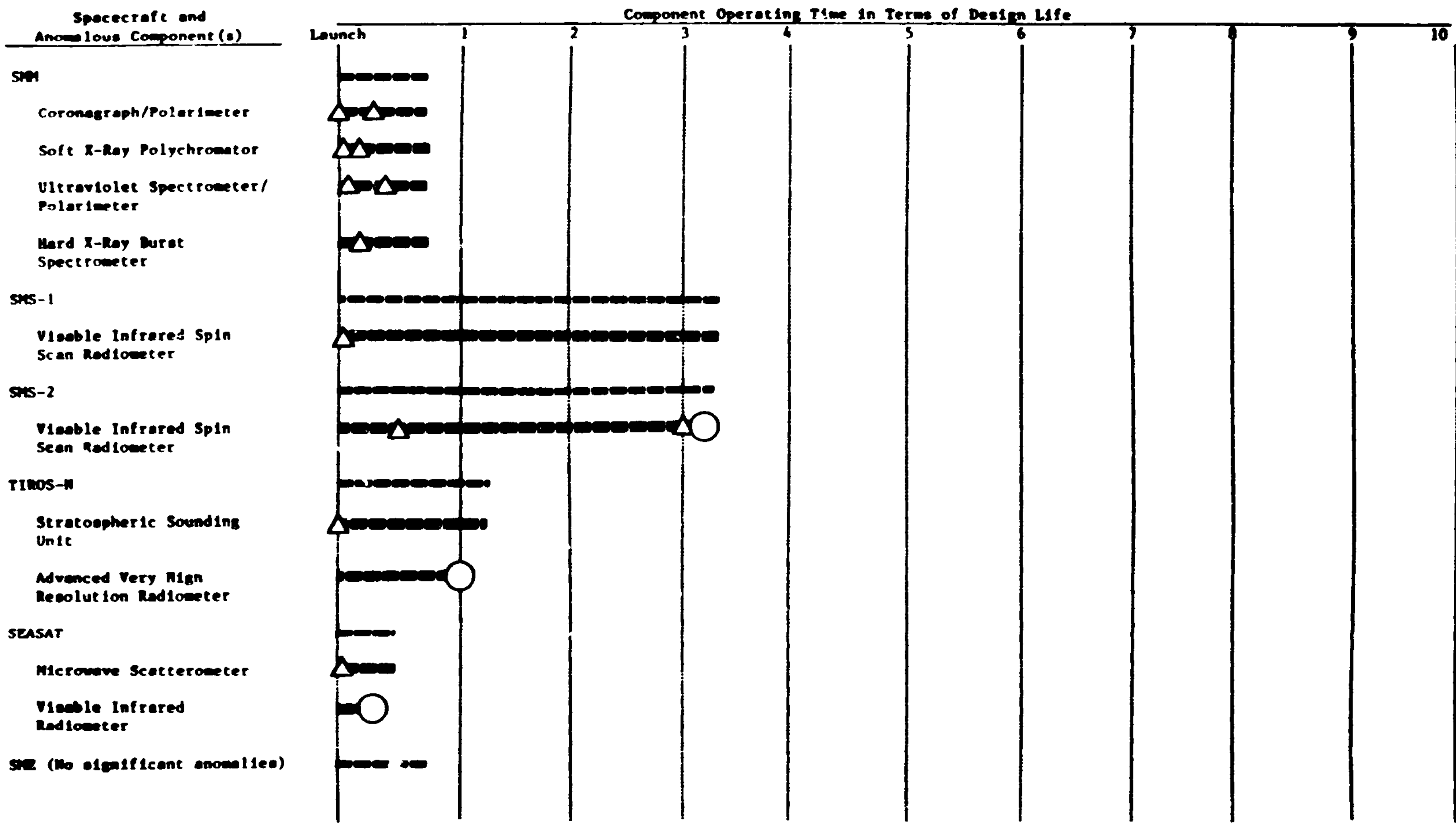
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Continued)



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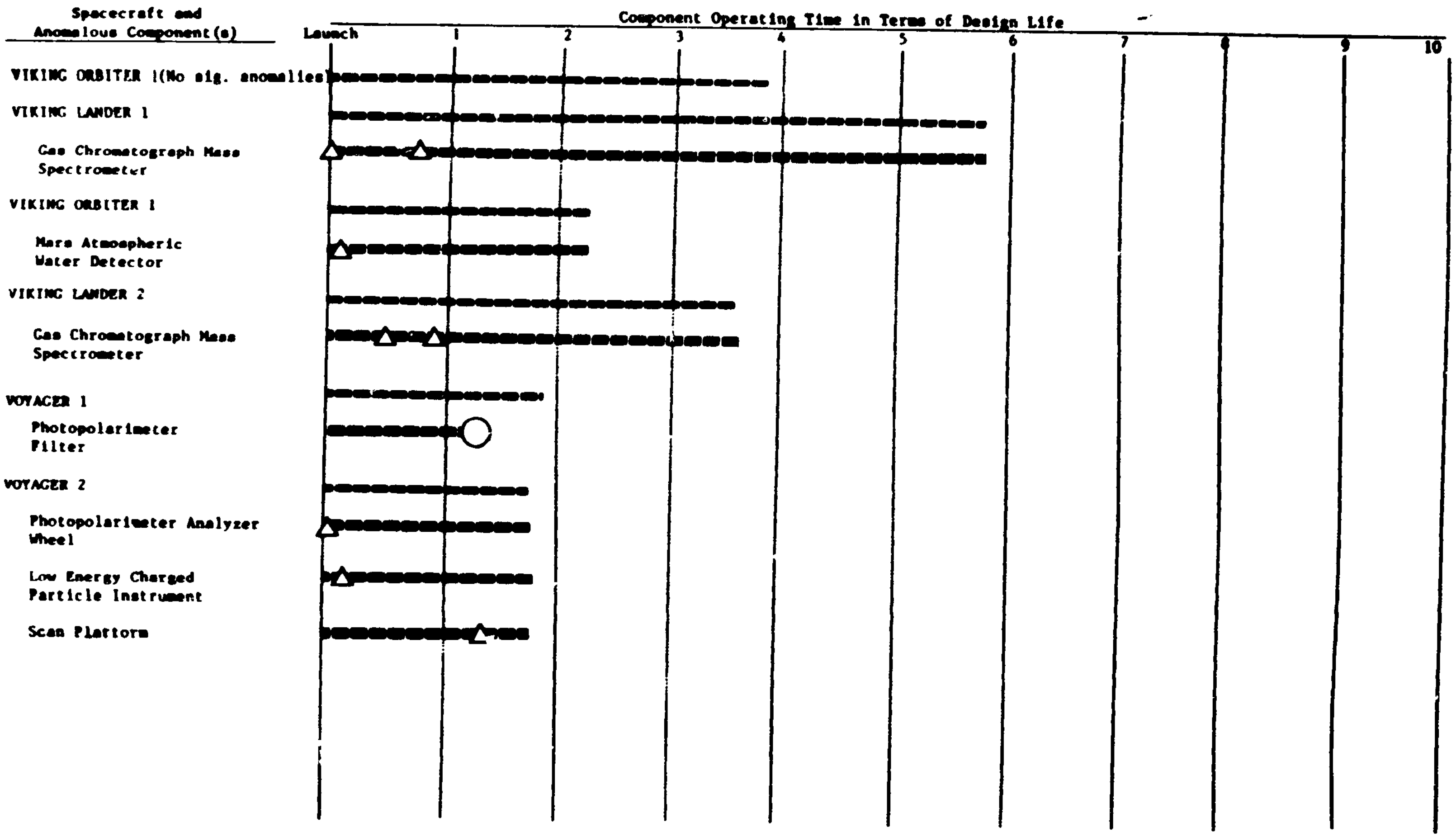
PAYLOAD SUBSYSTEM
SIGNIFICANT ANOMALIES AND PERFORMANCE SUMMARIES
(Concluded)



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